Science Communication Research from an Audience Perspective
–
Benefits and Empirical Insights for Science Communication in Switzerland and Beyond

Thesis (cumulative thesis)
presented to the Faculty of Arts and Social Sciences
of the University of Zurich
for the Degree of Doctor of Philosophy

by
Tobias Füchslin

Accepted in the fall semester 2019
on the recommendation of the doctoral committee composed of
Prof. Dr. Mike S. Schäfer
Prof. Dr. Senja Post

Zürich, 2019

Table of Contents

Figures

Acknowledgements

This thesis not only cumulates all of my peer-reviewed publications but also represents some of the most challenging, engaging and educational years of my life. The personal growth I have experienced and the amazing people I have met during this time are what made this doctoral journey a rewarding experience.

I would like to thank **Mike S. Schäfer** for introducing me to the academic world and supporting me throughout my academic upbringing. He not only provided the means but also the guidance and trust for my doctorate to succeed. I am also grateful to **Senja Post** who was kind enough to become my co-supervisor and always supported me with helpful career advice. Similarly, I would like to thank **Julia Metag** for leading me through my first published studies; these collaborations were key in motivating me to carry on as a researcher. Thanks go also to all my other co-authors who, without fail, provided valuable insights and contributions to our projects.

Special thanks go to friends and family that were closest to me during my PhD. **Tobias Keller** and **Valerie Hase** were not only pleasant office mates, but also my most important companions throughout the happiest and most maddening times of my academic journey. **Marko Ković** and **Adrian Rauchfleisch** also deserve mention: they were inspiring co-authors and their views have significantly shaped my academic values.

Most importantly, I would like to thank my mother, Theresia Füchslin. She cared for and supported me throughout my whole life, and she continued doing so throughout my PhD. She would have gone to any lengths to make my life easier. Knowing that she is always there for me gave me peace of mind during the challenging times of my academic path. This thesis is my big thank you to her.

I dedicate this body of work to both my parents.

One is and one would have been very proud of me.

Abstract

Science communication research is relevant and thriving. However, the field would benefit from practical insights, theoretical advances, systematic and long-term analyses, insights beyond Anglophone countries, and research on different audiences. These benefits are hard to reach in an ever-changing communication ecosystem. This text outlines how science communication research can use an audience perspective to respond to these challenges. Building on literature from (science communication) audience research, a framework that guides analyses with an audience perspective in science communication is proposed. On this basis, an audience perspective can employ segmentation analyses in particular to provide practical results, systematic analyses, and theoretical advances. The text further argues that people's general perceptions of information and messages enhance our understanding of audiences and that these insights could be expanded through differentiating them across various audiences. Overall, science communication research can heighten its relevance and success by applying an audience perspective.

1 The Need for an Audience Perspective in Science Communication

Science communication research is a growing field which is increasing in importance. The number of publications is steadily increasing in the three major English-speaking science communication journals (Guenther & Joubert, 2017), while the field is diversifying its research portfolio (Rauchfleisch & Schäfer, 2018). A simple explanation for this growth could be that science communication permeates everyday life, be it in popular culture, political discourse, or education (Meja & Stehr, 2017). However, prevalence does not equal relevance; there are two additional reasons that make science communication a relevant field of research.

On the one hand, science communication plays a relevant role in society. This is largely thanks to its main research object, scientific knowledge. Systematically gathered and verified knowledge offers the best insights that modern society has to offer in many daily situations (Bonfadelli et al., 2017). For example, parents need to decide how to keep their children healthy, school bodies want to optimize their educational approach, and businesses look for new technology to improve their products. For all of these problems, science holds potential answers. Additionally, scientific advances such as the germ theory of disease or the theory of general relativity, which fuelled improvements in our sanitation practices and technological developments, are arguably main drivers of modern society's development (Meja & Stehr, 2017).

Society at large is aware of value proffered by science. Surveys in various European countries and the USA not only show that the public generally trusts science and scientists but also that a considerable part of the population is highly interested in and wants to be informed about science (Burchell, 2018; National Science Board, 2018; Pew Research Center, 2019). Science's other stakeholders such as government bodies, related industries and politicians also show a growing demand for scientific information (Landrum, 2017). This interest in and demand for 'true knowledge' has intensified in times of 'alternative facts', and increased spread of misinformation online, and a resurgence in conspiracy theories (Bucchi, 2017; Scheufele & Krause, 2019). Considering that scientific knowledge is often highly complex, fraught with uncertainties, and therefore difficult to understand and communicate (Schäfer, Kristiansen, & Bonfadelli, 2015), it seems imperative that reliable research into how science is communicated and understood.

On the other hand, the science communication ecosystem is ever-changing, warranting continuous academic surveillance. Historically, changes like increased literacy created new audiences for popular science literature in the 19th century (Bensaude-Vincent, 2001), whilst the rise of mass media boosted coverage of scientific topics in the late 20th century (Bauer, 2012). Currently, science communication is undergoing three major and intertwined changes (Bonfadelli et al., 2017; Schäfer et al., 2015; Schäfer, 2017): *First*, science journalism is caught in a negative spiral with diminishing readership, income, and resources, while scientific institutions are professionalising their public communication efforts (Bauer & Gregory, 2008; Dunwoody, 2014; Schäfer, 2011; Scheufele, 2013). *Second*, a pluralization is taking place with new actors and formats appearing in the domain of science communication (Bubela et al., 2009; Schäfer et al., 2015). *Third*, digitalisation is reshaping science communication by heightening hopes for increased transparency of science and fears of social polarisation relating to controversial scientific issues (Brossard & Scheufele, 2013; M. Nisbet, 2014; Scheufele & Krause, 2019).

However, science communication research is also facing challenges. There is a lack of practical findings (Jamieson, 2017); a shortage of theoretical models of science communication (Bucchi & Trench, 2014); a need for more systematic and long-term analyses (Bauer, Allum, & Miller, 2007); an overly strong focus on Anglophone countries (Guenther & Joubert, 2017); and, with it, a need to focus research efforts on more and more diverse audiences (Scheufele, 2018).

As the primary goal of this text, I argue that scholars can address these shortcomings by approaching science communication research from an audience perspective. In times of increased user autonomy, media-induced fragmentation and fears of social polarisation (Lewandowsky, Ecker, & Cook, 2017; Napoli, 2012), an audience perspective has heightened relevancy when considering the research desiderata of science communication. I contend that a stronger focus on audiences of science communication helps to overcome all five shortcomings: Analysing audiences through segmentation analyses produces practical insights to science communicators about specific target groups. I will provide such practical findings mainly for Switzerland and also for Germany (section 3.1). If correctly undertaken, audience research favours systematic analyses (section 3.2), which in turn facilitates theoretical advances (section 3.3). As an additional benefit, these analyses fill the general research gap on audiences, providing insights for countries beyond the Anglophone context.

Before advancing these points, I discuss how audiences and the public are conceptualised in general audience research and science communication scholarly discourse, which builds a framework for audience research in science communication (section 2). I will then highlight additional aspects such as people's cognitions and their manifestations, which must be considered when researching audiences (section 4).

2 Approaching Science Communication from an Audience Perspective

'Audiences' as a concept is difficult to grasp (Hasebrink, 2008). Laclau (2005) describes terms like audiences and publics as empty vessels that carry too much ambiguity. Definitions of audiences are often simplistic, too general or are very specific to a certain research context. For example, simplifications as the "collective word to denote the receivers" (McQuail, 1994, p. 283) do not provide sufficient context, while a definition like «a collective label for the consumers of electronically mediated messages» (Radway, 1988, p. 359, as cited in Carpentier, 2011) implies a very specific, economics-orientated perspective on electronic media consumption. In the absence of an aim to find and provide a definition herein, it is nevertheless worth considering the different aspects inherent in audiences, how these aspects are reflected within the context of science communication and how they can be accounted for conceptually.

2.1 Conceptualizing Audiences

Audiences are not only an interesting issue for science communication. Researchers in communication science have developed varying approaches to analyse this key element in the communication process, ranging from more qualitative approaches in the cultural studies tradition, to those incorporating experimental designs in media effects research, and those developing more quantitative and survey-based descriptions of (mass) media audiences (McQuail, 1994). Four general audience aspects are relevant and discussed in all literatures.

2.1.1 Audiences as constructs

The first aspect is that *audiences are constructed* (Irwin & Michael, 2003; Stilgoe, 2007; Welsh & Wynne, 2013). It is important to note that audiences are perceived 'in the eye of the beholder'; they should not be seen as a natural entity, but one that is actively constructed and reflected accordingly. Bird (2003, pp. 2–3) says that «the "audience" is "everywhere and nowhere"», whilst Allor (1988, p. 228) summarises the concept with «the audience exists nowhere; it inhabits no real space, only positions with analytic discourses».

Common examples of audience constructions are «consumers, relatives, workers, and [...] citizens and publics» (Livingstone, 2013, p. 22). These labels, however, do not indicate the way in which these audiences were constructed. As one approach, researchers define key variables such as interest or media use to construct audiences empirically (Hasebrink, 2008). This is exemplified by a study in Germany which analysed media use frequencies over ten different media types, constructing four audiences with distinct media use patterns (Mangold, Vogelgesang, & Scharkow, 2017). A second approach is when researchers pre-define audiences based on theoretical assumptions: Grunig and Hunt (1984) developed the situational model of publics which defines problem recognition, constraint recognition, and involvement as key variables. Rather than using these variables for empirical analysis, they pre-defined four types of publics that can emerge: active, aware, latent, and non-publics. The final approach concerns self-constructed audiences, i.e. people perceiving themselves as a group which is held together by a collective identity (McQuail, 1994). Examples include social movements like the «Extinction Rebellion» advocating for climate change action or the «March for Science» standing up for scientists' relevance worldwide (cf. Welsh & Wynne, 2013). Established meso-level actors such as corporations, NGOs, charities, and associations can qualify as examples (Carpentier, 2011).

The notion that audiences are always constructed and not part of objective reality will be reflected and should be borne in mind in the upcoming aspects. This should also prevent researchers interpreting audience constructs deterministically (Morley, 2006), leading researchers to see audiences as a pragmatic construction (Fürst, 2014) or as a «taxonomic collective» (Ang, 1991, p. 33, cited by Carpentier, 2011), which will prove itself relevant to the current research objective.

2.1.2 Audiences as context-dependent

The second aspect is that *contextual factors* strongly influence audience constructions. Based on the idea that audiences either originate from society directly (e.g. social classes) or based on available media (e.g. internet users), we can group audience contexts as either people- or media-based (McQuail, 1994): *Media-based context factors* describe how media channels and media content influence audience constructions. This is exemplified by the «locality» of audiences and how this audience-feature evolved over time following changes in media-based context factors. Historically, audiences like theatre-goers were automatically associated with sharing the same geographical space. When the emergence of mass media drastically changed the media ecosystem, scholars also started speaking of locally dispersed audiences. With the rise of digital technology, internationalisation and the digital space became a relevant expansion of the locality of audiences. As users are frequenting different contents and formats, audiences are fragmented into sub-audiences, proving increasingly challenging to track. (Napoli, 2012).

People-based context factors stem from individual or group level characteristics. McQuail (1994) lists a number of factors: Social and cultural circumstances describe how age, education and social resource distributions can affect the way audiences are construed. In the same way that media structures change, social circumstances can alter over time. For example, an ageing population might lead to an increased interest in more nuanced conceptions of older TV audiences. Similarly, people's leisure time, their media use, tastes and interests are subject to structural changes, which, in turn, will influence audience constructions.

Researchers can gauge a myriad of contextual factors. The cultural study approach to audiences has prioritised these contexts, studying and describing in depth how specific audiences consume specific media in specific circumstances. This attention to detail comes with a downside, however. A researcher can become tied up in contextual factors and lose track of reaching conclusions that can be applied more generally. It is important to find a balance between considering the importance of context, without considering too many factors and losing analytical focus (Morley, 2006).

2.1.3 Audiences between activity and passivity

The third aspect describes the *activity* level of audiences. Audience research has, similarly to media effects paradigms, oscillated between notions of *active and passive* audiences (Carpentier, 2011; Livingstone, 2013; B. O'Neill, 2011).

Audience research throughout the rise of mass media could only suspect the large effect the media would have on the public. This public was conceived as a collective mass without a common goal or rules, with impersonal internal relations, and which was highly susceptible to media messages (Maletzke, 1963). This idea of a *passive* mass pervaded through numerous media effects studies and their interpretation of the media's impact at that time (McQuail, 1994).

Later audience research, particularly in the cultural studies tradition, focused on a more *active* conception of audiences (Livingstone, 2013; Nightingale, 2011). Hall's (2001) encoding-decoding model exemplifies the core idea behind the active audience in that whilst media messages carry intentional messages from the communicator, the receiver then actively interprets those messages, and might interpret those messages in a way unanticipated by the sender. Authors including Fiske (1992) with his concept of «audiencing» and Ang (1991) put forward similar ideas concerning highly active audiences. These conceptions hone in on the audiences receiving the message and consider them to be the most active participant in the communication process. Consequently, research within this paradigm often produces in depth qualitative analyses that describe how audiences actively interpret media messages within their specific contexts (Morley, 2006).

Audiences are not only active when it comes to decoding messages but also when creating messages. Carpentier (2011) divides audience activity into «interaction with media content» and «participation in media production». The former reflects the aforementioned active interpretation process, the latter refers to an active media production process divided into two types: «Content-related participation» describes the how an individual participates in the production of media content, while «structural participation» applies when non-professionals engage in media production decision-making.

Carpentier's additional differentiation is significant because it emphasises that audiences both actively interpret and communicate themselves, thus showing the relevance of «talking back» (McQuail, 1994, p. 286), i.e. there is two-way communication and role-switching between original communicators and their audience. Bruns' (2008) «produsage» concept also encapsulates this idea by reframing online users as «produsers» who not only use information but also contribute in various forms ranging from simple reactions, to comments, and to creating extended content.

Both notions of highly active and passive audiences are ideal-type conceptions of publics. Overall, researchers are conscious of this, but the power and freedom of media audiences is often overstated and romanticised (Livingstone, 2013; Morley, 2006). In this vein, it should be noted that the literature's oscillation between favouring active and passive audience concepts shows that audiences are capable of being both active and passive depending on the specific context.

2.1.4 Audiences as collectives, aggregates, or individuals

A fourth aspect through which to differentiate audiences is to consider them on a macro versus micro level, or, in other terms, as *collectives, aggregates or even individuals*. Some of these differences were implicit in previous examples (e.g. «taxonomic collectives»), which demonstrated the importance of disentangling this dimension. A good starting point is to outline the difference between *collective* and *aggregated* audience concepts.

Many audience concepts suggest that an audience may present as a *collective* unit, which is its own entity with certain characteristic features. Such audiences might be understood as a «huge, living subject» (Ang, 1991, p. 61). The «mass» audience is the most prevalent example of a collective audience. Individual subjects are not seen as relevant units; what matters is the audience as a macro-construct with specific yet universal traits (Carpentier, 2011). The mass audience does not possess a self-identity, is heterogeneous, unguided by any rules, is there to be acted upon, and has impersonal internal relations (Maletzke, 1963). Other examples of audiences as collectives include complete groups represented in market segments or social groups like the working class, the academic community, or the political public (McQuail, 1994).

Aggregated audience concepts conceptualise individuals that, taken together, constitute the audience. The goal is to focus on «overlapping subsets of individuals» and their individual «social-economic» profile (McQuail, 1994, pp. 288–289); these individual profiles then produce an aggregated audience profile. Nevertheless, at the heart of the matter, this number demonstrably stems from those individuals and subgroups that might differ from the aggregate's average and can always be considered in isolation.

The focus on *individuals* can lead to the other extreme: not contextualising them as an audience at all. Many authors researching digital communication could be subsumed under a position stating that «audiences are dead—long live the user!» (Livingstone, 2013, p. 21). This seems a reasonable perspective in a context of digital technology where individual data can be tracked and used for user-specific rather than audience-specific communication. Instances like the Facebook-Cambridge Analytica data scandal clearly show that the internet allows complete focus on the individual in online persuasion efforts (Walker, Mercea, & Bastos, 2019).

What further shapes the collective versus aggregated character of audiences are social ties within these audiences. For instance, the mass audience is seen as a loose collective that, if any, has only impersonal ties among its constituents. A collective described as a community or social class automatically invokes notions of stronger social bonds. While it remains unclear, how social ties affect concepts of aggregated audiences, the literature discusses collective audiences with strong social ties as a unique circumstance. This is exemplified by Tönnies (1887),who contrasts audiences along a spectrum of «Gesellschaft» to «Gemeinschaft». The former can be translated as «society» and implies a lack of identifying group connections and group identity. The latter («community») implies the existence of a group identity. Carpentier (2011) emphasises that these social ties can vary in character, resulting not only in audiences as communities but also to audiences as organised, active social groups like the aforementioned Extinction Rebellion or the March for Science.

2.2 Conceptualizing Audiences in Science Communication

Audiences play an important role in science communication literature, which predominantly talks about the public rather than about audiences. This distinction is theoretically important because some authors see the public as a special type of an audience. As Butsch (2011, p. 154) puts it: «to define audiences as publics is to conceive them enacting their role of "good citizens".» When publics are understood as «citizen audiences» (Butsch, 2011, p. 161), audiences are conceptualised in a political context enacting their role as democratic citizens (Livingstone, 2013). This implies that theoretical models in science communication predominantly discuss audiences from a normative perspective (Raupp, 2017); they discuss why and how citizens should be informed about scientific issues so they can assess and democratically shape science's role in society (Bauer et al., 2007; Bucchi & Trench, 2014). Therefore, significance is placed both on communicating with an audience, and on how that public behaves politically. At the same time, the «public» in science communication texts often simply represents the society-level receiver of scientific information, but «nobody seems to know exactly what the public is» (Neidhardt, 1993, p. 339). It remains a frequently used yet ill-defined term from which the reader may infer the exact definition (Burns & Medvecky, 2018; Felt, 2000). Henceforth, we consider the public a unique example of an audience in science communication, where the focus lies on the receivers of scientific information and how that information shapes perceptions of scientific issues. I do not discuss any normative implications that such publics present to the relationship of science and society.

However, there are the striking similarities between the key aspects of audiences discussed in section 2.1 and the way in which the public is discussed in science communication literature. After highlighting these similarities, I will introduce additional audience aspects that have received attention in science communication. I conclude by synthesizing these aspects and proposing a framework that assists in the consideration and analysis of audiences in science communication research.

2.2.1 Reflections of audience research in the publics of science communication

The way in which science communication literature discusses audiences mirrors many of the aspects discussed in general audience research.

Active and passive publics in science communication. The first reflects the oscillation between active and passive audience constructions in the normative models of science communication. A number of theoretical models and concepts (e.g. PUS, PEST, mode 1 & 2, deficit model) describe the relationship and communication between science and society (for an overview, see Schäfer et al., 2015, pp. 15–22). These models have evolved, changed in relevance over time, and promote different concepts of the public. Earlier phases were dominated by deficit models, which assumed that the public lacked in knowledge or positive attitudes about science, which should be remedied by the scientific system in a top-down, one-way communication effort (Bauer et al., 2007). Bucchi and Trench (2014, p. 9) suggest: «the traditional usage of *public* evoked a notion of passive and target-like readers and spectators, often addressed and defined paternalistically». Welsh and Wynne (2013, p. 540) go further to say the UK public in the second half of the 20th century were perceived as a «passive non-entity». This reflects the concept of the passive mass audience from general audience research. This time, the *mass* are not news media consumers but «a body of rather undifferentiated, passive consumers of knowledge» (Felt, 2000, p. 10). This similarity is not coincidental; mass media were identified as one of the best channels through which to achieve the educational goals of the deficit model assumptions (Bauer, 2012; Gregory & Miller, 1998).

Newer models of science communication such as «public engagement with science» or «science in society» advocate for bottom-up communication efforts with two-way communication. They encourage the value of the public as an active contributor to the discussion of science policy issues and knowledge production through engagement in formats like citizen science (Schäfer et al., 2015). Again, we see a paradigm in science communication, reflecting general audience research and conceptualising the public as highly active and powerful.

Current science communication formats reveal that, implicitly, both conceptions of active and passive audiences are present. For example, Public Service Announcements remain popular one-way, top-down communication efforts designed to educate a broad audience about issues like vaccination (CDC, 2019). At the same time, multiple countries incorporate consensus-conferences as a tool where the public can actively meet and discuss policy issues with designated experts (Scheufele, 2011). However, there is not only a back and forth in current formats, historical development also features dynamic changes. Bensaude-Vincent (2001) describes how the scientific establishment in France at first highly appreciated the public as an important stakeholder in the scientific enterprise. Only with time and specialisation came a need to shift towards a more detached form of science communication aimed at a public conceived as a passive mass. For the UK, Welsh and Wynne (2013) outline how the recent commitment to engagement and dialogue has led to a new concern of an overly-active and potentially anti-science public that enacts its power through social movements.

Some scholars also comment on the celebration and stigmatization of overly active and passive concepts of the public (Einsiedel, 2007). They argue that because there is not just one public, we can expect more active and passive audiences within the public: «publics can also be inattentive, unmotivated, and, yes, ignorant» (Einsiedel, 2000), which serves to justify the co-existence of both one- and two-way communication models (S. Miller, 2001).

Not monolithic, but collective audiences. Most audiences in science communication are perceived as collective audiences. This is certainly true in practice when considering scientists and experts' perceptions of lay audiences. Studies show that scientists mostly view the public at large as a homogenous audience that lacks in interest and knowledge. If they do differentiate, they separate the public into multiple collective audiences that are, again, largely homogenous and incapable of understanding science (Besley & Nisbet, 2013; Stilgoe, 2007; Young & Matthews, 2007). For example, one study described that pesticide researchers divide their audiences into one large group that lacks scientific literacy and another smaller «good sense» group of lay people (Blok, Jensen, & Kaltoft, 2008). Another study showed that industry experts in the chemical sector divided the public into consumers with product preferences, neighbours living close to factories and the general public. The latter two groups were considered to be homogenous, believed not to trust experts and devoid of potentially valuable knowledge (Burningham, Barnett, Carr, Clift, & Wehrmeyer, 2007).

The scholarly discourse on publics and audiences also largely consists of collective audience concepts. A recurring theme is the debunking of the idea that there is a «monolithic» public, which is largely uniform in its knowledge, perceptions, and behaviour regarding science. Researchers have long replaced the public in the singular with «publics» in the plural (Featherstone, Weitkamp, Ling, & Burnet, 2009). This does not entail a conceptual switch to aggregated audiences, however. Scholars speak of collective audiences like the «Attentive and Interested Public» (J. D. Miller, 1986), the «disengaged» (Burns & Medvecky, 2018), or invited and uninvited publics (Wynne, 2007). This is also reflected in Scheufele's (2018) commentary, which argues on the level of collective audiences when speaking of «multiple audiences» and a need to expand our understanding of «different scientific publics» such as the «underserved audiences».

This focus on collective audiences is not without critique. Some scholars argue that collective audience concepts are too simplistic and disguise the fact that audiences are aggregates of individuals «dynamically constituted by changes in social contexts» (Burns & Medvecky, 2018; Jasanoff, 2014, p. 23). On the other hand, Welsh and Wynne (2013) propose that an overly individualistic conception of audiences leads scholars and policy makers to overlook collective audiences such as social movements, thus denying them their differences and discursive standpoints. It transpires, however, that an emphasis on contextual factors and the dynamic nature of audiences is not mutually exclusive with discourse that is based on collective audience concepts, as will be demonstrated in the following paragraphs.

Audiences as highly contextual. Collective audience concepts in science communication are often accompanied by discussions on and prioritisation of the importance of contextual factors (Jasanoff, 2014; Lewenstein, 2002). Many refer to the audiences' social context or what was earlier subsumed under the category of people-based context factors (Einsiedel, 2000; Metag & Schäfer, 2018; Scheufele, 2018). For example, Felt (2000) mentions the most recurring factors as gender, age, education, personal experience, social background, economic status, work environment and ideological background.

Einsiedel (2000, 2007) adds to this list of factors but understands audiences in science communication as aggregates of individuals «playing multiple roles». This perspective allows for a conclusion that any given individual, depending on the context, can be part of many different audiences, even if the social context of that individual remains stable. These contextual factors are «issues, times, and places»; variables so dynamic that audiences are termed as «issue-centered, transient, occasional». Scheufele (2018) references additional «cultural context» factors like regulatory systems, political systems, media structures, and educational systems.

Media-based context factors also play an important role in science communication. The literature points out that changes in media structures directly affect the way we conceived audiences. A historical perspective can highlight key shifts in media structures and their effects on audience concepts. Adding to the earlier example, Bensaude-Vincent (2001) also argues that the emergence of the mass communication of science in 19th century France turned a hitherto valued public into «science consumers», which increased the gap between scientists and the public, which gradually led to the idea of the «ignorant masses». Significantly, this shift was spurred by mass media and the improvement of their dissemination.

Assessments of current changes in the media ecosystem do not have the same benefit of hindsight, but they can highlight pertinent areas of change. Science communication is undergoing three major and interconnected changes (Bonfadelli et al., 2017; Schäfer et al., 2015; Schäfer, 2017): *First*, science journalism is experiencing a downward trend with diminishing readership, income and resources, while scientific institutions are professionalising their public communication efforts (Bauer & Gregory, 2008; Dunwoody, 2014; Schäfer, 2011; Scheufele, 2013). *Second*, a pluralisation is occurring with new actors and formats appearing in the domain of science communication (Bubela et al., 2009; Schäfer et al., 2015). These new actors are not only scientific institutions but also non-governmental organisations and individual science communicators with large followings. Examples for new formats that affect science communication are microblogs such as Twitter (e.g. Büchi, 2017), YouTube as the dominant video platform (e.g. Welbourne & Grant, 2016), Wikipedia (e.g. Moy, Locke, Coppola, & McNeil, 2010), crowdfunding platforms (e.g. Schäfer, Metag, Feustle, & Herzog, 2018), or «Citizen Science Online Games» (e.g. Füchslin, 2016). *Third*, digitalisation is reshaping science communication (Brossard, 2013; Brossard & Scheufele, 2013; Bubela et al., 2009). Not only is digitalisation one of the main drivers of science journalism's diminishing resources and the emergence of new actors and formats, it also adds negative and positive prospects. Digital technology helps science to follow its own principles and maintain openness and transparency (M. Nisbet, 2014). However, audiences are fragmenting across channels and formats, resulting in potential entrapment in ideological echo chambers, leading to more polarised views over time (Scheufele & Krause, 2019).

2.2.2 Particular foci of audiences in science communication

Science communication literature discusses several new facets that are less prominent in general audience research.

The issue of issue-specific audiences. Different scientific issues are key components when analysing audiences in science communication (Einsiedel, 2000; Jasanoff, 2014). One might also speak of *issue-based audiences* as an add-on to McQuail's (1994) people- and media-based audiences. Issues are relevant because science can address many different issues spanning health, climate change and technology, for example. Even when narrowly defining science as natural sciences, endless numbers of issues and sub-issues with different scopes and characteristics are covered. These differences in issues give rise to different audiences. For example, it appears unlikely that the same group of people would have the same attitudes towards science versus biology versus stem cell research (Einsiedel, 2000).

Most studies on audiences focus on a handful of individual issues like science in general (e.g. Kawamoto, Nakayama, & Saijo, 2011), climate change (e.g. Maibach, Leiserowitz, Roser-Renouf, & Mertz, 2011), or nanotechnology (e.g. Anderson, Brossard, Scheufele, Xenos, & Ladwig, 2014). While most research focuses on post-normal science issues associated with greater and public uncertainty (Funtowicz & Ravetz, 1985), there are also examples of audiences of highly contested issues such as «food» that have received little scholarly attention (Blue, 2010). Analyses have not yet compared audiences for different issues within one study. Instead, comparisons of one issue across different people-based contexts are frequent, i.e. in different countries (e.g. Pullman, Chen, Zou, Hives, & Liu, 2018).

Against this backdrop, Scheufele (2018) suggests that we start to systematise whether we focus on specific scientific issues, compare different issues, or focus on science in general. Additionally, issues can be differentiated between their level of controversy, politicization, or scientific uncertainty. Lastly, we can incorporate where an issue stands within a wider media context and consider its stage in the issue-cycle. It seems that such systematic expansions would bring new findings to the science communication literature relating to audiences. A focus on specific issues is thought to be both more practical for science communicators and more interesting from a policy perspective (Featherstone et al., 2009; Scheufele, 2018). A means of doing so would incorporate issue-specific theoretical models to predict different audiences. Such an example exists, but it prompts further investigation (e.g. Featherstone et al., 2009).

Scholars' engagement with disengaged audiences. Another research focus is science communication's interest in «disengaged» audiences. They are population segments that display any combination of low levels of knowledge about scientific facts and processes, little to no interest in science, a lack of engagement with science, or even negative attitudes towards science. Examples are commonplace in segmentation studies: the «disengaged», «doubtful» and «dismissive» about climate change in the USA (Maibach et al., 2011); the «health uninformed» regarding media use (Rodgers, Chen, Duffy, & Fleming, 2007); or the «low-interest» cluster regarding science in Japan (Kawamoto et al., 2011). They are also present as «disengaged» and «non-publics» in studies that theoretically define audiences (Featherstone et al., 2009; M. Nisbet & Markowitz, 2014).

These groups are interesting as they constitute both a threat and a worthwhile challenge. If the disengaged expand in number, they can call into questions the relevance and legitimacy of a scientific issue (J. D. Miller, 1983). If science communication can provoke interest in science in a disengaged person, this is arguably a more significant gain than increasing someone's already favourable attitude towards science (Scheufele, 2018).

Some scholars criticise the negative conception of these disengaged groups. Burns and Medvecky (2018) argue that these audiences are often poorly conceptualised and empirically only based on a small and incomprehensive set of variables. They contend that «disengaged» groups are likely far more complex, for example they consist of people with a subversive mindset, and that communication efforts «that aim to address the people within the category are, for that reason alone, unlikely to succeed» (Burns & Medvecky, 2018, p. 123). A more culturally-sensitive investigation by Dawson (2018) supports this notion, showing that science communication efforts in the UK barely reach low-income, minority ethnic groups and leave them with the sense of isolation and powerlessness.

The subset of the population called «disengaged» plays the role of what used to be the monolithic, passive and uneducated public. Their conceptualisation is arguably used too deterministically. As a result, these groups might have been identified as important but not conceptualised adequately to facilitate effective communication.

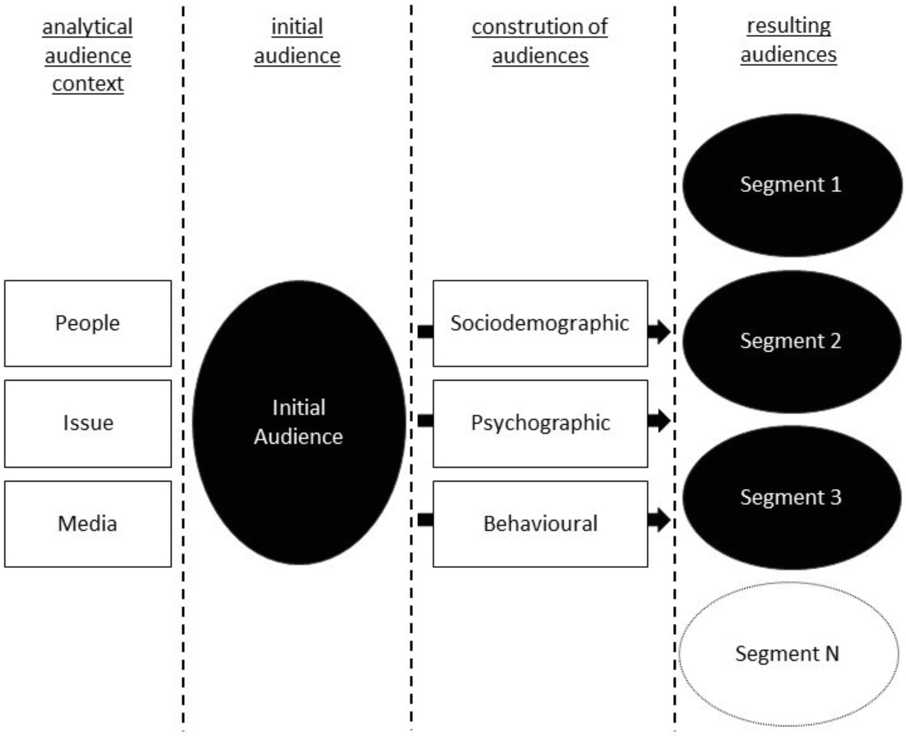
The relationship between experts and audiences. Science communication literature entertains a conceptual difference between scientists and the public. This leads to a demarcation problem for science communication research with an audience perspective because audiences are often considered as separate from scientists as a reference group (Burns & Medvecky, 2018).

This demarcation is problematic because scientists represent a considerable part of the audiences of science communication. As science is a highly specialised endeavour and audiences are, amongst others, issue-specific, any given scientist or expert will be an expert in some domains but a layperson in other domains (Felt, 2000). Vice versa, many audiences, particularly in a science-policy context, do not just consists of laypeople but also include experts (Einsiedel, 2000). An additional concern is that the public, therefore, remains a poorly defined group which is often contrasted with science as another poorly defined group. This artificial split creates a hegemonic perspective where science is better than the public, while it remains unclear what the two categories actually stand for (Burns & Medvecky, 2018). Therefore, it is important to remember that scientists are not necessarily separate from audiences when constructing audiences of science communication.

2.2.3 Researching audiences in science communication

Based on the previous two sections, I suggest the Audience Perspective Framework, which is aimed at constructing and reflecting audiences in science communication (Figure 1). The framework is heuristic and applies to both quantitative and qualitative audience analyses. It can be described through a) the analytical audience context, b) characteristics of the initial audience, c) audience construction variables, and d) the resulting audiences and their characteristics.

Figure 1: The Audience Perspective Framework



a) The analytical audience context. Context significantly influences any audience construct (Einsiedel, 2000). I divide this section into three general and partially overlapping domains: people-, media- and issue-based factors. *People-based factors* capture the social and cultural context of audience concepts. They subsume anything that could be understood as socio-demographic factors in the traditional sense, but also include macro-attributes like countries or political systems (Felt, 2000; Scheufele, 2018). *Media-based factors* describe the media structures surrounding the potential audience. There are different ways of describing them systematically. One way focuses on different levels like media sources (e.g. newspapers, television, or the internet), media channels within a source like the internet (e.g. news-websites, video platforms, or social media), or media content within a specific channel (e.g. different YouTube videos) (McQuail, 1994). *Issue-based factors* concern the scientific issue(s) of analytical interest. Besides identifying the issues, researchers can also consider their level of politicisation, level of uncertainty, and their position in the issue-cycle (Scheufele, 2018). Like the other two factors, this list can be expanded with other potentially interesting variables.

These three domains are only one way of categorising the different aspects and variables. One could argue that media structures are also a type of cultural context and should be a people-based factor. The three domains should be seen as a heuristic that directs researchers to three important aspects of audience constructions in science communication. Researchers can always expand and adjust the domain-variables. The simplicity of the domains also serves as a reminder that too much focus on context can limit analytical clarity (Morley, 2006).

b) The initial audience. The analytical context shapes an initial audience, i.e. a total population set within analytically chosen parameters. For example, an analysis might only focus on women with tertiary education living in Switzerland and investigate the way they use the internet to research climate change. This context already limits the population to a subset of people, which could already be seen as the audience of interest or could be shaped and differentiated even further. Researchers should consider the size of the initial audience, what sample of the audience they are working with and how they conceptualise the initial audience's activity versus passivity and collective versus aggregate composition. These aspects will become more interesting after this audience has been further differentiated.

c) Construction of audiences. Empirical analyses can further construct the initial audience. Often this means a differentiation according to selected variables, i.e. creating different sub-audiences. It can also mean a more detailed description of the initial audience based on selected variables by setting a specific analytical focus. These two approaches can be combined, for example, by differentiating the initial audience according to one set of variables and then further describing the different resulting audiences with another set of variables.

Researchers can construct their audiences through sociodemographic, psychographic, or behavioural variables (Metag & Schäfer, 2018). *Sociodemographic* variables are common descriptors like age, gender and level of education. For science communication, one can also consider people's social proximity to science, i.e. whether they have a scientific background or personally know a lot of scientists. This might also include the demarcation between laypeople and experts (Felt, 2000). *Psychographic* variables concern people's cognitions. Relevant cognitions in science communication are people's attitudes, trust in experts, interest, knowledge or scientific literacy (Schäfer, Füchslin, Metag, Kristiansen, & Rauchfleisch, 2018). They are generally shaped by the issue context. If an analysis is focused on the issue of climate change, attitudes towards and knowledge about climate change are more relevant than attitudes towards science in general. *Behavioural* variables represent information about people's (intended) behaviour. Regarding science communication, media use behaviours and other forms of contact with a scientific issue are most relevant. Again, relevant behaviours are influenced by the issue-context.

d) Resulting audiences. The previously outlined construction process leads to the resulting audiences. Even if variables like media use were only used to describe the initial audience (rather than differentiating it), this is still an active construction process because it highlights a certain view of the initial audience. If variables are used to differentiate between sub-audiences, the construction process is more apparent because it will result in multiple audience constructs. Continuing with the earlier example, researchers can differentiate the initial audience of highly educated, Swiss women using the internet in relation to climate change according to their online media use behaviour such as their frequency of social media use. This differentiation could lead to a focus on two resulting audiences of high- and low-volume users.

At this point, researchers should certainly consider the size of the resulting audiences, whether they are interpreted as collective or aggregate constructs, and how they fall within the continuum of active and passive audiences (Einsiedel, 2007).

Activity is particularly interesting in science communication when rather than simply assessing a heightened passive or active media use, a more passive or active role in interacting with scientific knowledge is considered. This is an adaptation of Carpentier's (2011) «participation in media production» as a «participation in scientific knowledge production». In that sense, participatory formats like citizen science are «content-related participation», while an active engagement in science policy matters represent a form of «structural participation».

3 The Benefits of an Audience Perspective in Science Communication

Science communication research is facing at least five challenges currently: *First*, practical science communication research remains minimal, which is why scholars have called for more practical conclusions from the «science of science communication» (Fischhoff, 2013; Jamieson, 2017; Office of Science and Technology & the Wellcome Trust, 2001; Scheufele, 2013). *Second,* on a related note, there is a shortage of conceptual models of science communication (Bucchi & Trench, 2014). The literature offers historically inspired and normatively charged models of the relationship between science and society (Raupp, 2017; Schäfer et al., 2015), which are often too general for many research contexts. Alternatives include specific media effect models (e.g. Winter & Krämer, 2012), or adoptions of general communication models like the framing approach (Bonfadelli, 2017). The field lacks models like the «risk perception attitude framework» dedicated to the specific issue of risk communication (Rimal & Real, 2003). *Third*, there are not enough systematic and long-term analytical efforts (Bauer et al., 2007; Metag & Schäfer, 2018; Scheufele, 2018). While surveys like the «Science and Engineering Indicators» (National Science Board, 2018) or the «Science Barometer Germany» (Wissenschaft im Dialog, 2018) collect long-term data, their analyses are mostly descriptive. *Fourth*, scholars call for more research on audiences of science communication (Bucchi & Trench, 2014). Despite calls for more in-depth analyses of audiences going back almost two decades (e.g. Einsiedel, 2000; S. Miller, 2001), leading scholars are still urging the field to explore more diverse audiences, as discussed above (M. C. Nisbet & Scheufele, 2009; Scheufele, 2018). *Fifth*, research shows a strong focus on Anglophone countries, which makes it more difficult to generalise research findings (Guenther & Joubert, 2017).

These challenges can be addressed by approaching science communication from an audience perspective, which is relevant in its own right: Audiences are not only an integral part in the communication process, most classical communication models incorporate some form of an audience, receiver or public (McQuail, 1994). Audiences are also a key element in the theoretical and normative science communication discourse (Schäfer et al., 2015).

This key element is undergoing two major changes in the current media ecosystem (Napoli, 2012). Digital media allows users more *autonomy* in terms of selecting contents and formats but also in creating and commenting on content themselves. Consequently, users extend across different contents and formats, *fragmenting* audiences into smaller sub-audiences that are increasingly harder to track. Communication scholars are concerned about these developments. When people are increasingly isolated, they might join communication networks comprised of only like-minded people in so-called «echo chambers» (Jamieson & Cappella, 2008; Lewandowsky et al., 2017). As aforementioned, this scenario could not only limit public political discourse in the short-term but also lead to social polarisation (Barberá, Jost, Nagler, Tucker, & Bonneau, 2015), where people in echo chambers are never challenged and their views are reinforced. While such theses have been criticised (Garrett, 2017), they remain plausible and under-researched in a science communication context (Scheufele & Krause, 2019). On top of that, specific changes in the science communication eco-system (see 2.2.1), such as diminishing resources for science journalism, pluralization of actors and formats and digitalisation (Schäfer, 2017), are also likely to affect the way in which audiences are constructed and self-construct.

In this section, I outline how an audience perspective can address all five challenges by bringing three direct advantages to science communication research. An audience perspective is prone to producing practical results through the method of segmentation analyses, which also addresses the general need to explore more audiences and to research more non-Anglophone countries. It facilitates systematic research efforts, and it presents the opportunity for theoretical advances. I will use my co-authors' and my body of work (see 7) to exemplify these assertions.

3.1 Practical Insights Through Segmentation Analyses

Segmentation analyses are one of the best analytical tools through which to gain practical insights into audiences, particularly in science communication. Their principle is to divide a population into homogenous subgroups that are distinct from each other (Hine et al., 2014). To do so, researchers need to choose one or more variables of interest (henceforth called «cluster-variables») and use their expressions to categorise the population. Approaches to categorising people range from theory-driven segmentations (where researchers know in advance which groups will emerge), to data-driven approaches (where a statistical procedure will discover optimal subgroups). For example, Featherstone et al. (2009) applied a theoretical segmentation and used three binary variables to sort subjects into one of four predefined audiences according to the situational model of publics (Grunig & Hunt, 1984). In data-driven fashion, a UK survey posed 77 questions and used a combination of factor and cluster analyses to discover six potential audiences of science communication (Ipsos MORI, 2011).

There are several different approaches to data-driven segmentation analyses, and because these methods are explorative, there is not one best method. Researchers need to choose their approach(es) based on the structure of their data (number, type, and distribution of variables). The most robust approach is often to compare segment-solutions across different methods to find robust solutions (Chapman & Feit, 2019). In general, quantitative procedures can be divided into distance- and model-based methods. *Distance-based methods* like k-means clustering and hierarchical clustering use decision-algorithms to pair subjects into different groups. These algorithms use the clustering-variables to calculate a distance-measure, then assess how close (groups of) subjects are to the other (groups of) subjects.

Depending on the exact method, distances are used to pair or divide subjects into groups whose subjects are maximally close or far away from each other. *Model-based methods* like latent class analysis find a regression model that uses the cluster-variables to predict how likely each subject is to fall into one of a number of predefined latent categories. These categories represent the different subgroups and researchers have to predefine their number. This time, an algorithm finds the model that produces subgroups that have the least shared variance across as many predictors as possible. As I outlined in (Schäfer, Füchslin et al., 2018), analyses in science communication typically use either latent class analysis suitable for ordinal variables, or a combination of factor analysis and distance-based clustering, which reduces the number of variables first and enters continuous factors into, for example, k-means clustering (Chapman & Feit, 2019; Langeheine & Rost, 2013).

Segmentation analyses are interesting for science communication for various reasons. *First*, segmentations help to tailor science communication efforts and make them more effective. They produce informative typologies of distinct target audiences, which can inform the design of science communication efforts, in line with the agenda of «the science of science communication» (Jamieson, Kahan, Scheufele, & Schäfer, 2017). Social marketing research often employed segmentation analyses because optimised groups with distinctive consumer traits are a perfect target for efficient communication efforts. While social marketing is ultimately aimed at increasing sales, science communication has goals like attitudinal or behavioural change that appear structurally similar and also benefit from optimised target groups. A promising path to explore is to deploy specific knowledge about different audiences to frame science specific communication messages in a way that resonates best with these target audiences (Druckman & Lupia, 2017). Studies in health communication have also shown that tailoring messages according to different segments increases the effectiveness of the message (Noar, Benac, & Harris, 2007). *Second*, they give actors who want to communicate science a heuristic but more sophisticated understanding of the diversity of their audiences. This helps to break down the simplistic notions of largely uniform and uninterested audiences in which many experts and scientist believe (Besley & Nisbet, 2013). *Third*, segmentation analyses produce segments that can be understood as collective audience constructs for theoretical discourse (see 2.2.1). Identifying recurring population segments enhances theoretical discussions about the relationship between science and society with empirically based insights. *Fourth*, science communication research has numerous high-quality data sets available through which segmentation analysis can be conducted. The field could gain valuable insights, both theoretically and empirically, from using more segmentation analyses on already available data sets (Füchslin, 2019). *Fifth,* while issues like social polarisation and echo chambers are widely discussed in communication science, many questions remain about science-related context issues. Segmentation analyses are a tool through which scientists can model and monitor various groups over time and can thus inform this area of research.

Segmentation analyses in science communication have been widely used for specific issues like climate change and health (Metag & Schäfer, 2018), and have only recently experienced an uptake for the general issue of science (see Füchslin, 2019 for an overview). Overall, the audiences represented in these analyses remain under-conceptualised (Metag & Schäfer, 2018; Scheufele, 2018). This is why one finds calls for more segmentation analyses in science communication (M. C. Nisbet & Scheufele, 2009; Scheufele, 2018), despite interest in different population groups going back multiple decades (e.g. J. D. Miller, 1986).

I have contributed to the recent uptake of segmentation analyses in science communication by co-authoring four different segmentation analyses, three of which allow conclusions for science communication in Switzerland. I calculated the final cluster solution in all of them. The segments will be presented within the Audience Perspective Framework (see 2.2.3) and the practical insights derived from these solutions will now be discussed.

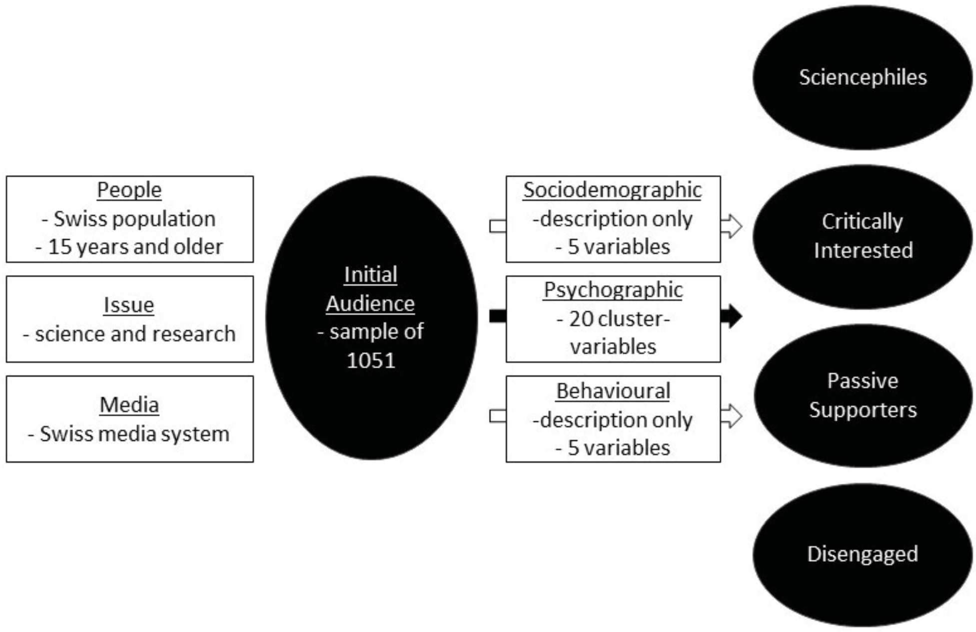
3.1.1 The Different Audiences of Science Communication (Schäfer, Füchslin et al., 2018)

A first empirical study with practical relevance, which can be placed within the Audience Perspective Framework (Figure 2) is Schäfer, Füchslin et al. (2018) (see 7.1).

As it is the first of three segmentations of the Swiss population, the Swiss media context is of particular relevance. The overall media system is comparable to the democratic corporatist model (Hallin & Mancini, 2004). Public service broadcasting is widely established, while newspapers are widely read and based on a pluralistic national press, which is highly professional and self-regulated (Künzler, 2013).

Science plays an important role in Switzerland. Citizens and stakeholders are included in the governance of science, while policy-makers actively rely on findings and reports from scientists (Mejlgaard, 2018). Switzerland is arguably the most innovative country in the world (Cornell University, INSEAD, and WIPO, 2019), prioritises the educational sector, and is home to highly ranked universities (Schäfer, Füchslin et al., 2018; Vogler & Post, 2019).

Figure 2: Schäfer, Füchslin et al. (2018) within the Audience Perspective Framework

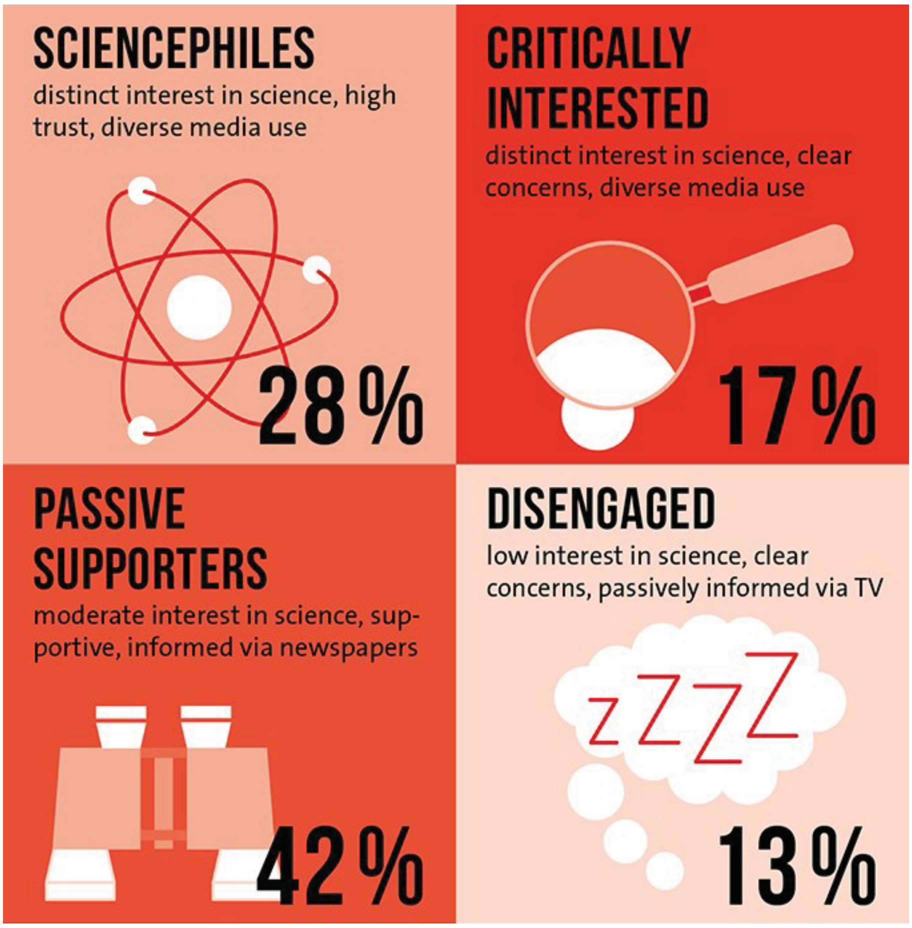


Consequently, science communication plays an important role in Switzerland. Approximately 4% of Swiss journalists work for science and education desks (Dingerkus, Keel, & Wyss, 2016; Metag, Maier, Füchslin, Bromme, & Schäfer, 2018). Similarly, about 5% of media coverage and usage are linked to scientific topics (fög, 2017). According to a study on science news coverage in legacy media from 2009 to 2013 (Eisenegger & Gedamke, 2013), three quarters of science-related media content in Switzerland displayed a positive tonality and consisted of superficial reporting based on press releases. The remaining quarter consisted of more substantial and critical reporting, often resulting in articles that are more negative. These findings reflect that science journalists in Switzerland view themselves as «objective mediators who aim to depict reality as it is and provide their audience with necessary orientation» and «less often as watchdogs aiming to publicize erroneous developments and problems» (Kristiansen, Schäfer, & Lorencez, 2016, p. 135).

Within this science-related media context, the analysis focuses on the Swiss population (aged 15 years and older) and the issue of «science and research». This falls within a general issue-context, comparable to other national surveys asking about «science and technology» (e.g. Eurobarometer, 2010). It is also the first of three segmentation studies in my dissertation that segmented the Swiss population with data from the 2016 Science Barometer survey. The nationally representative survey sample consists of 1051 cases and captures Swiss adults' perceptions of, attitudes towards, and knowledge of science and research. To construct our audiences, we only used psychographic variables, i.e. 20 attitudinal variables measuring cognitive, affective, and conative attitudes towards science and research, as well as hopes and reservations, subjective and informational norms regarding science and research, and attitudes towards the relationship between science and society. Socio-demographic and behavioural variables were considered in a second step to clarify additional findings on certain features of the constructed audiences. Socio-demographic indicators include age, sex, and education and people's proximity to science. Concerning behavioural variables, we looked at people's contact with science and research through various offline and online media, as well as other real-life contact with science (e.g. going to the zoo or science event).

Because our data was predominantly ordinal and we did not want to create ad-hoc factors, we ran a latent class analysis, but also compared our results for robustness with results from a combination of factor and hierarchical cluster analysis. This resulted in a solution with four segments (Figure 3).

Figure 3: Infographic: Four Audiences of Science Communication in Switzerland



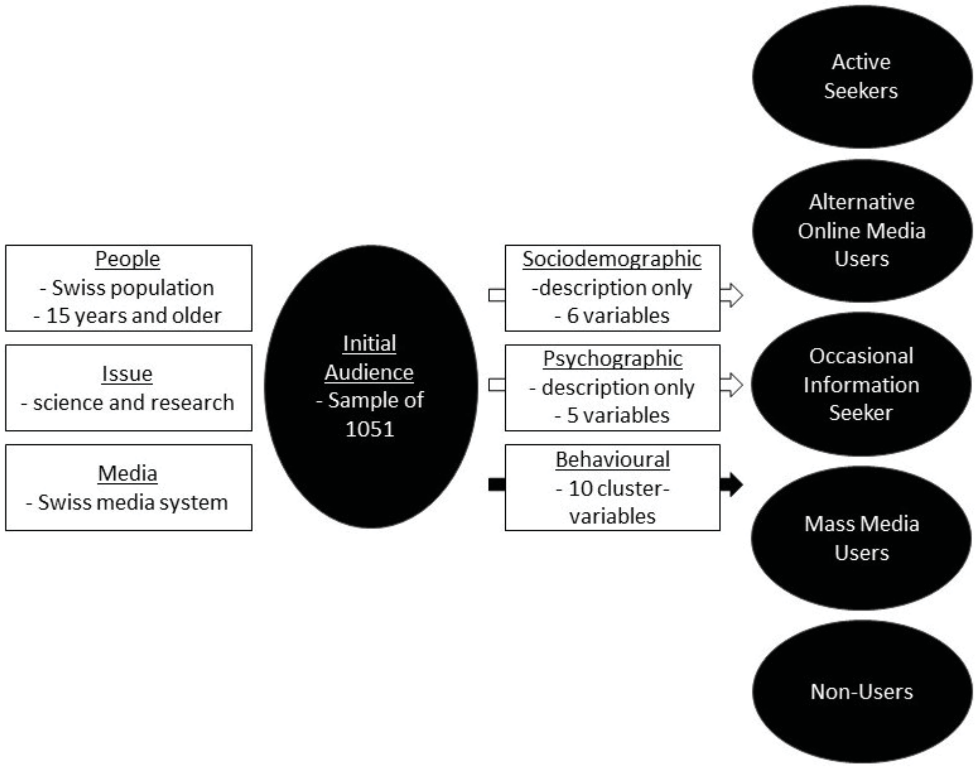
The four segments represent four attitudinal types in Switzerland towards the issue of science and research. Additional analysis also showed that the groups differ considerably in their media use behaviours. For example, the «Sciencephiles» get in contact with science and research through a wide range of online and offline sources, while legacy media are the most important source for the «Passive Supporters». We did not differentiate between scientists and non-scientists when constructing the segments, but indirectly referenced this information in our sociodemographic description. We can infer from the index for people's social proximity to science that the «Sciencephiles» also consist of a considerable number of scientists.

The segments are understood as collective audiences that have a relative population share and represent abstract archetypes with differing attitudes. We cannot break these audiences down into an aggregate level because they are inferred from a representative data set. Judging by their media use, the groups display different activity levels of using scientific content. Groups like the «Sciencephiles» and the «Critically Interested» have the tendency to use the internet actively and find information about science, while the other two groups have a more coincidental exposure to the issue via legacy media. This does not mean that a group like the «Disengaged» is an exclusively passive group. As Burns and Medvecky (2018) suggest, we should keep in mind that people in this group have valid and often active attitudes that lead to a more indifferent perspective towards science and research. In a qualitative follow-up study, Koch, Schäfer, Hermann-Giovanelli, Saner, and Metag (forthcoming) were not only able to substantiate the validity of our segments but also show that people from all segments can display nuanced thoughts and perspectives on science.

3.1.2 Segments of Science-Related Media Use in Switzerland (Metag et al., 2018)

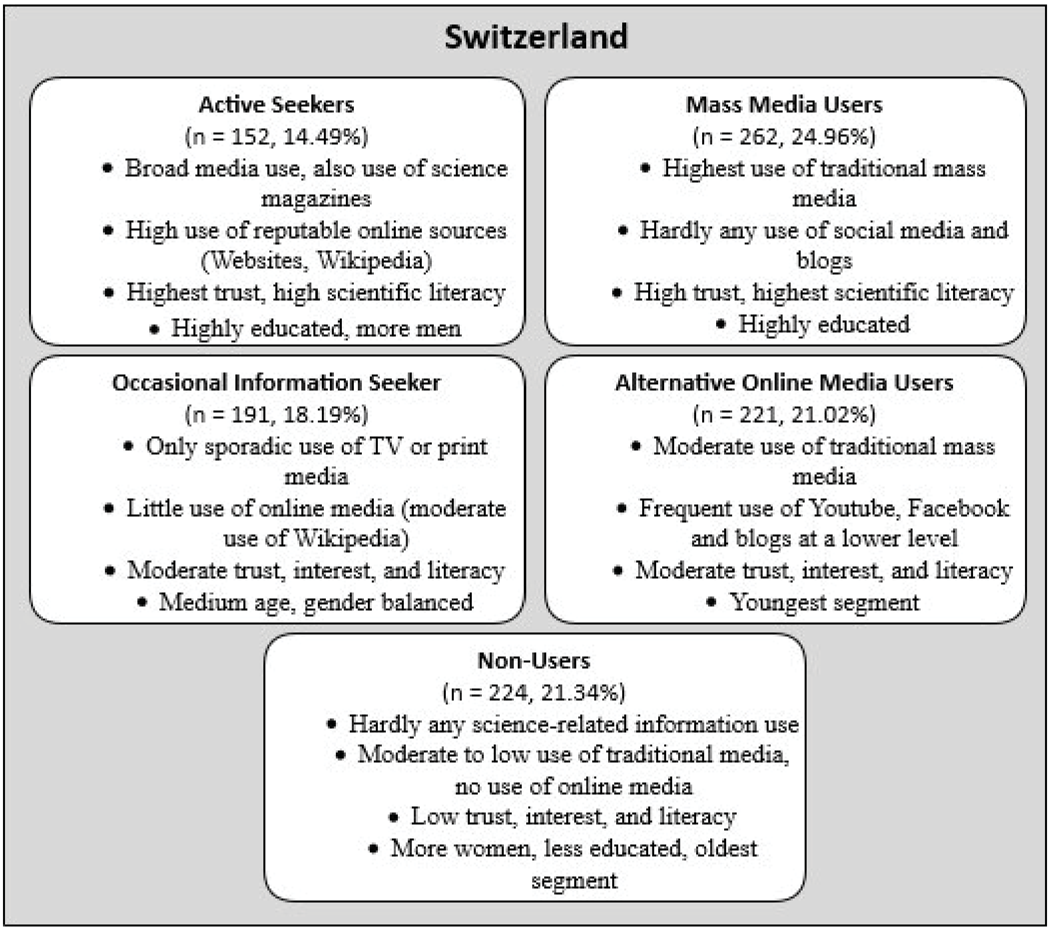
The Metag et al. (2018) study consists of two segmentation analyses focusing on Germany and Switzerland, respectively (see 7.2). Having calculated the Swiss solution, I will only focus on the results for Switzerland. The context of the analysis is very similar to that previously (Figure 4): it focuses on Switzerland, the Swiss media system and the issue of science and research. Based on the Science Barometer 2016, we constructed our audiences with 10 behavioural variables, measuring people's offline and online media use frequency on science and research. The analysis results in segments that can be understood as representations of people's science-related media repertoires. A set of socio-demographic, psychographic and behavioural variables (the majority of which were present in Schäfer, Füchslin et al., 2018) were used to supplement the description of the constructed segments.

Figure 4: Metag et al. (2018) within the Audience Perspective Framework



We used latent class analysis to construct five audiences with distinctive media use patterns (Figure 5). The five segments represent five types of typical science-related media use patterns in Switzerland. Further descriptions showed that the groups also differed in their sociodemographic make-up and attitudes towards science and research. For example, «Active Seekers» are on average 15 years younger, three times more likely to have tertiary education, and are significantly more interested in science than the «Non-Users». Again, we did not distinguish between scientists and non-scientists when constructing the segments. The proximity to science index suggests that people with the strongest social ties to science or are scientists themselves are most likely to be «Active Seekers» or «Mass Media Users».

Figure 5: Infographic: Segments of Science-Related Media Use in Switzerland



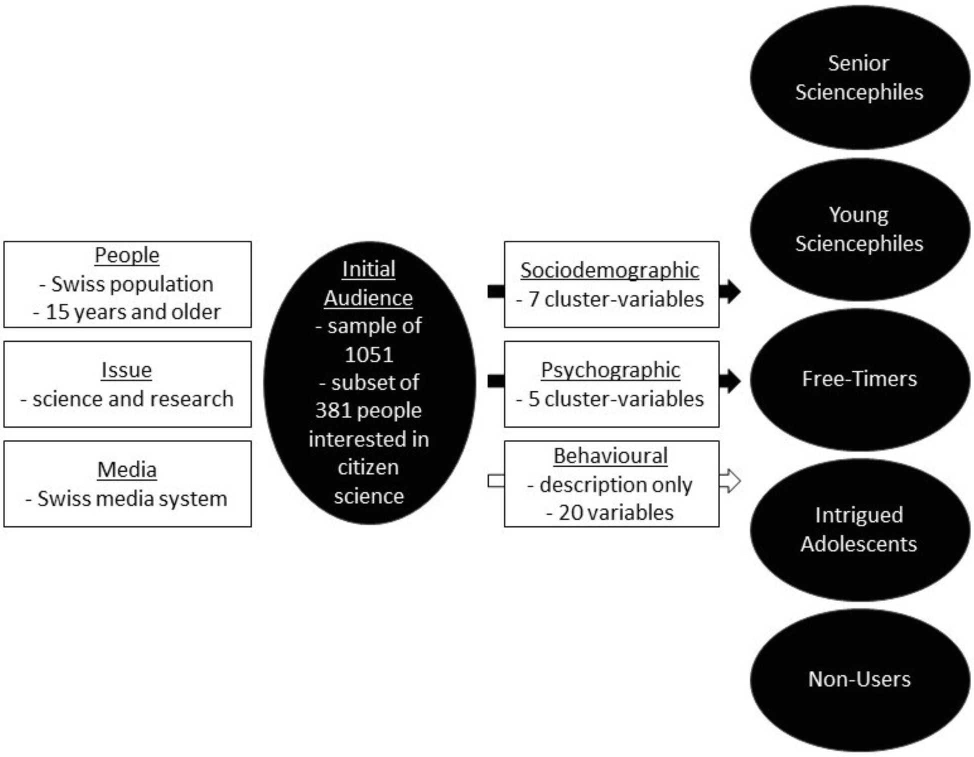
Source: content and format adapted from Metag et al. (2018)

These five collective audience constructs are particularly useful when describing a presumed level of activity of the audience. They are conditioned on people's media use frequencies. Legacy media use can be interpreted as more passive, while online media use is generally more active; it can be divided into more active sources such as Wikipedia and more passive ones like video platforms. The «Active Seekers» have a much higher rate of online media use, but still enjoy watching content on video platforms. This shows that such collective audiences need to be understood as both active and passive. More precise insights into activity and passivity depend on circumstances outside of the scope of this study.

3.1.3 Target Segments for Citizen Science in Switzerland (Füchslin, Schäfer, & Metag, 2019)

Füchslin et al. (2019) analyses people's general interest in participating in scientific research projects (see 7.3). Public reports on citizen science project participants suggest that project organiser failed to address or overlooked certain target groups. We explored whether there were general sociodemographic and attitudinal predictors for the population's interest in citizen science and which target groups would be willing to participate in Switzerland. As a result, the paper consists of two analytical steps: a regression model and a segmentation analysis.

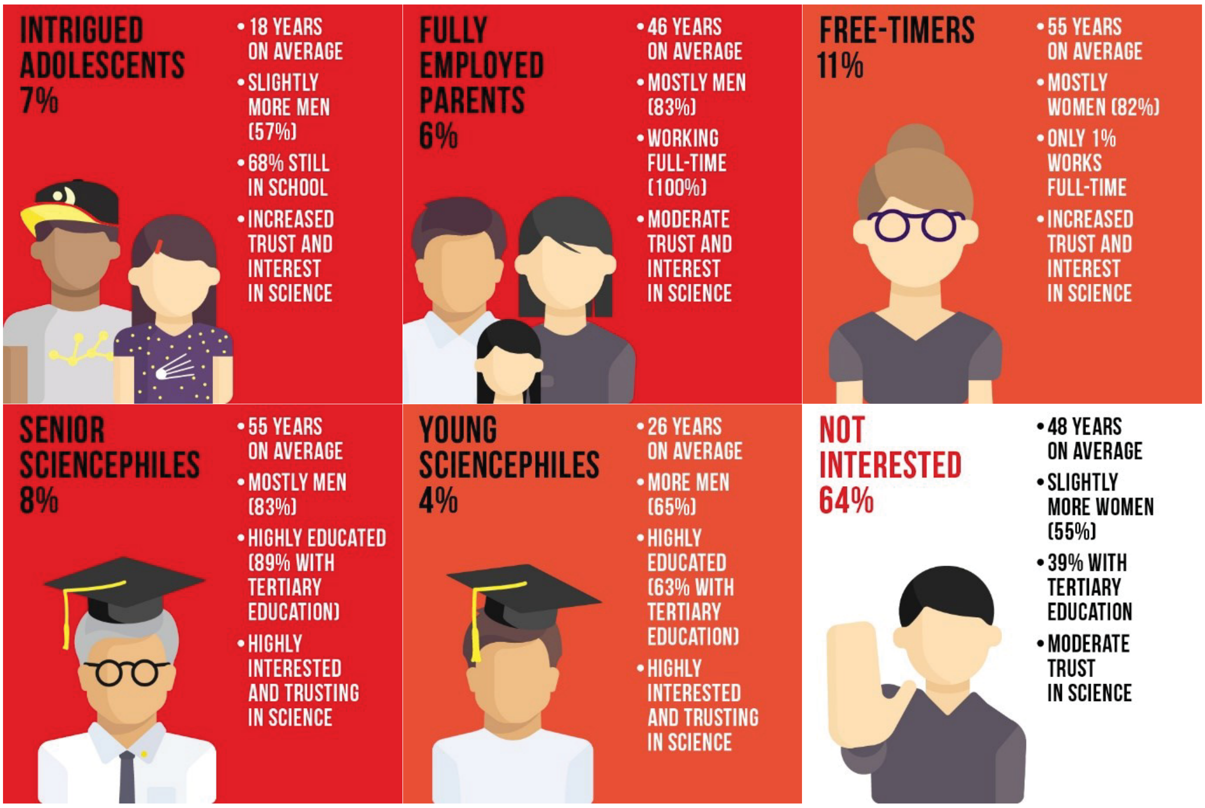
Figure 6: Füchslin et al. (2019) within the Audience Perspective Framework



The segmentation analysis also uses the 2016 Science Barometer data and shares all the people- and media-based context factors of the previous two segmentations (Figure 6). However, this segmentation focuses on a subset of the population, namely those 36.2% of people that were interested in participating in scientific research projects. In that sense, the study is pertains specifically to the issue of citizen science, although the cluster-variables themselves were related to the issue of science and research. We used 13 cluster-variables, a combination of socio-demographic and psychographic variables, to construct six target groups for citizen science in Switzerland. We further described these segments by considering all the behavioural variables that featured in previous analyses, i.e. media use and alternative contact with science and research.

Using latent class analysis, we constructed five segments within the subset of 381 people that are interested in participating in research. We added the a priori excluded 670 people as a sixth group, which was predefined as the «Non-Citizen Science» segment, also referred to as the «Not Interested» (Figure 7).

Figure 7: Infographic: Target Segments for Citizen Science in Switzerland



These collective audience constructs have a different character than the four audiences of Schäfer, Füchslin et al. (2018), despite both representing the Swiss population. This reiterates how the goal of the analysis shapes the construction and perception of audiences. In this study, a focus on social diversity led to increased attention to socio-demographic variables. Additionally, the issue-based focus on citizen science means that the five audiences can be understood as *active* because they are interested in ‘participation in scientific knowledge production’ (cf. Carpentier, 2011).

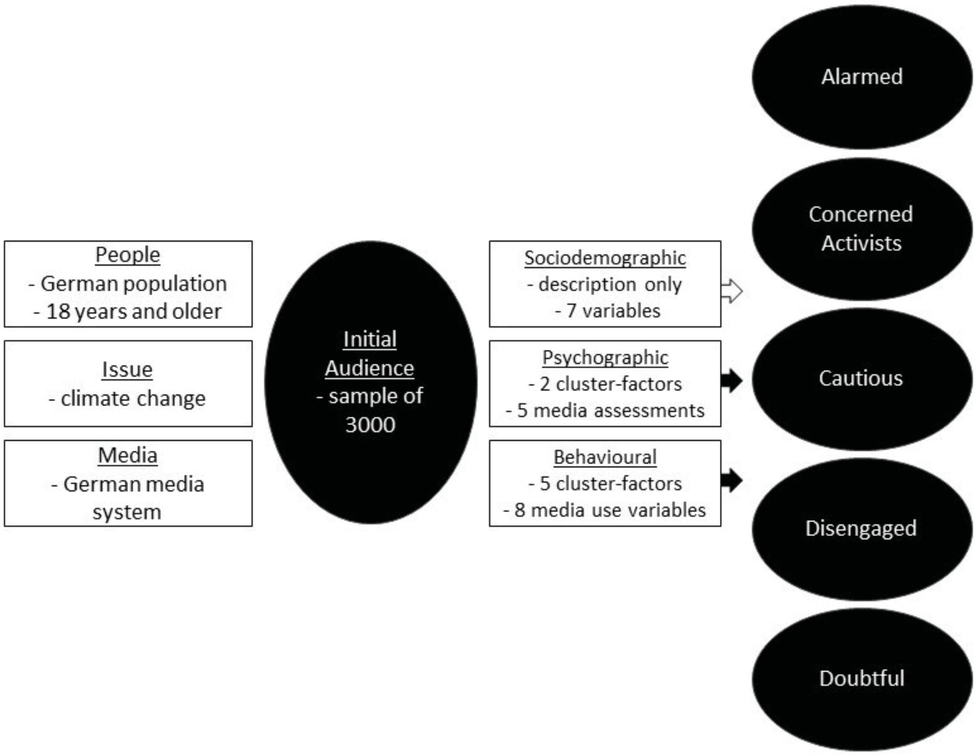
A similarity between this study and Schäfer, Füchslin et al. (2018) is the description of behavioural variables as an additional step, which uncovers significant differences, even though the segments were not conditioned on these variables. This allows for clear practical conclusions to be drawn when considering target groups for citizen science projects. For example, groups yet to participate in scientific research projects can be reached through increasingly creative communication channels: «Intrigued Adolescents» through YouTube, «Fully Employed» Parents and «Free-Timers» in zoos and botanical gardens.

3.1.4 Global Warming’s Five Germanys (Metag, Füchslin, & Schäfer, 2015)

The fourth segmentation study demonstrates that the proposed framework applies to any science communication issue (see 7.4). Our study was inspired by the «Global Warming’s Six

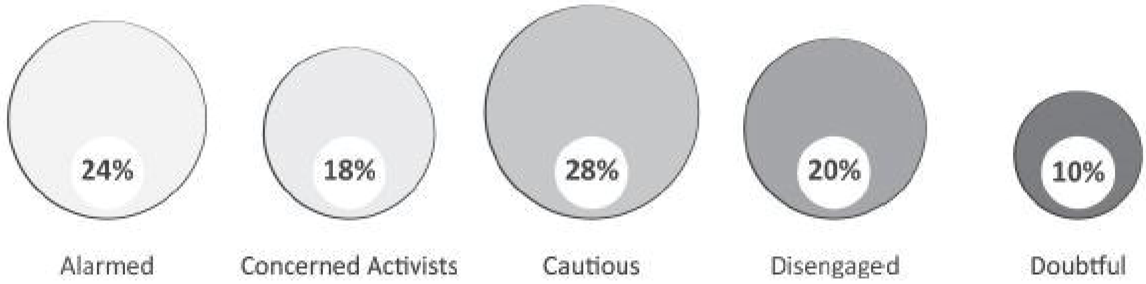
Americas» study (Maibach et al., 2011) and considered the issue of climate change in the context of the German population (18 years and older) in 2011 (Figure 8). As climate change is a more specific issue, we know from the quantity of print media articles and Eurobarometer surveys that the issue was most salient around 2007, but still regarded as a very serious issue by two thirds of the population in 2011. Within this context, we analysed a sample of 3000 survey respondents. To construct our audiences, we used a combination of psychographic indicators like beliefs about climate change, environmental awareness and concern about climate change, as well as behavioural variables covering climate change-related behaviour and political activism. Typical sociodemographic and behavioural variables regarding mass media use were relevant as additional descriptions.

Figure 8: Metag et al. (2015) within the Audience Perspective Framework



The segmentation analysis employed a factor analysis to condense the 39 cluster-variables into seven factors, which were used in a hierarchical cluster analysis. This resulted in five segments representing the overall attitudinal and behavioural tendencies of the German population when it comes to the issue of climate change (Figure 9).

Figure 9: Infographic: Global Warming's Five Germanys



Source: Metag et al. (2015)

Additional descriptions of segment's media use showed some significant but not markedly and Metag et al. (2015) strong differences between the groups. Compared to the «Disengaged», the «Alarmed» had read about climate change 0.6 scale-points more often that the Disengaged on the internet and only 0.1 points more often on television. These differences between very different segments are lower than expected on a 5-point scale. This exemplifies that differences in variables that were not previously part of the segmentation process can be interesting but do not always produce dissimilarities. As a result, the practical value of these segments when it comes to communication efforts is lower than if media variables were included as cluster-variables.

As was the case in previous segmentations, the resulting clusters can be understood as collective audience constructs. While we have two audiences that represent a more negative stance towards the issue of climate change, we do know more specifically how this translates into levels of activity and passivity. For example, we know that these two groups are much more passive in issue-related political activism. Schäfer, Füchslin et al. (2018) did not have clear behavioural indicators and speculation was required on activity levels based on a segment's interest combined with use of the internet as a source. Clarity is given when some behavioural variables are included and it is not only a segment's name that induces speculative conclusions.

3.1.5 Discussion of the Practicality of Segmentation Analyses

All four segmentation studies employ an audience perspective and show how such analyses can not only deepen our understanding of population structures but also deliver practical insights. While this was not the studies' primary aim, the resulting ideal types are collective audience constructs with distinctive characteristics that can guide communication efforts. For example, science journalists might feel encouraged by a quarter of the Swiss population being very interested in science and research, thereby giving relevance to their profession. A group like the «Critically Interested» also shows that a critical perspective on science and its limitations is valued by a considerable part of the Swiss population and that science and research has a following that view science positively and can be reached with interesting messages through legacy media. Even the findings for climate change in Germany show that the topic reaches almost all audiences on a regular basis, laying the foundation to change the outlook of the two more passive segments, i.e. the «Disengaged» and the «Doubtful».

These insights arise despite some noticeable differences between the studies' setups: Schäfer, Füchslin et al. (2018) and Metag et al. (2018) related to science and research in general, Füchslin et al. (2019) was tailored to the issue of citizen science, and Metag et al. (2015) focused on climate change. They employed different combinations of sociodemographic, psychographic and behavioural variables to construct their audiences. Schäfer, Füchslin et al. (2018) only used psychographic measures, Metag et al. (2018) only used behavioural variables, while Füchslin et al. (2019) and Metag et al. (2015) deployed a combination of psychographic and either sociodemographic or behavioural measures.

As a result, the four studies demonstrate various levels of practical insights. One might believe the level of practicality depends on their variables focus, but this is not the decisive factor. I would argue that the Füchslin et al. (2019) citizen science segmentation is more practically valuable than the Metag et al. (2015) climate change segmentation despite similar approaches to their audience construction. The citizen science analysis is more applicable as it found pronounced differences beyond the cluster-variables, thus adding differences in media use behaviour as distinct segment characteristics. Metag et al. (2018) was solely conditioned on science-related media use, yet its practical value was suboptimal because it lacked clear differentiation between individual's psychographic make-ups. It seems clear that differentiating and presenting information about all three categories of variables (socio-demographic, psychographic and behavioural) provides the most useful practical insights. Having such distinct differences depends on the structure of the data and cannot always be manufactured. The citizen science segmentation turned out to have variations in all aspects, even though clear findings were not guaranteed for the media use behaviours.

These findings could have a heightened practical application through, on the one hand, clearer and more numerous measures of people's behaviours. An increased number of specific media use measures to deconstruct effective communication channels in all four studies would also be appreciated. On the other hand, more benefit could be derived from data featuring the relevant cases instead of a purely a representative sample. Then researchers could identify each person's socio-demographic, psychographic and behavioural type and make informed decisions based on the three different construction processes.

3.2 Systematic Analyses of Different Audiences of Science Communication

There are not many systematic and long-term analyses of audiences available in science communication. Findings are more or less advanced depending on the issue-context. Research in climate change communication has focused on audiences and produced a number of long-term and international analyses (Hine et al., 2014). Research on the issue of science in general has not developed that far, whilst most examples are summaries of long-term survey statistics (Bauer et al., 2007). This is particularly true for segmentation analyses, where scholars have called for more systematic analyses (Metag & Schäfer, 2018; Scheufele, 2018). The few systematic efforts consist of one prolonged segmentation analysis of the British public's attitudes towards science (e.g. Ipsos MORI, 2011) and a cross-national comparison of attitudinal segments (Okamura, 2016). While the former changed its analytical approach over time and was conducted by a market research company, the latter had a limited set of six survey questions available.

On the one side, the lack of systematic efforts is surprising because they might be able to monitor audiences over time. Many of the ongoing changes in science communication like digitalisation and power-shifts between science journalists and other communicators directly affect audiences. It affects through which channels audiences encounter science-related content as well as the authors and quality of said content (Schäfer, 2017). Against this backdrop, some authors suspect that audiences might end up in echo chambers and be prone to social polarization (Metag & Schäfer, 2018; Scheufele & Krause, 2019).

On the other side, the lack of systematic efforts is unsurprising since audiences are an empirical challenge. Constantly shifting media environments reshuffle analytical contexts (Chaffee & Metzger, 2001), while audience's fragmentation across different media channels makes it harder to track, identify and locate them (McQuail, 1994; B. O'Neill, 2011). In science communication, this this challenge is reinforced by the fact that issue-contexts can drastically shift with the emergence of new key technologies or the politicization of hitherto neutral issues (Scheufele, 2013).

In spite of this, there is great potential for more systematic research to be conducted in the science communication field (see 7.5). As I summarised it in Füchslin (2019, 2):

> «Science communication research is ideally suited to realise such systematic efforts: First, science communication is still in the early phase of employing segmentation analyses. This allows us to think about systematic efforts before different research groups are set in their incomparable ways. Second, our field has established many nationally representative surveys like the annual 'Science and Engineering Indicators' in the United States, the 'Eurobarometer' or the 'Wissenschafts-barometer' in Germany or Switzerland (for an overview, compare Bauer and Falade, 2014). This means that researchers can draw on a lot of high-quality survey data, some of them available for several countries and cross-national comparative analysis, and some of them available over long periods of time, partly for decades. Third, most of these surveys already have substantial topical overlap. Almost all of them assess people's attitudes towards, knowledge of and perceptions of science and often share measurements of a handful of key theoretical dimensions (cf. Bauer, 2009; Besley, 2013). While there remain crucial differences between these surveys – some ask about 'science & technology', others about 'science and research' – the overlap is big enough to identify a common topic like 'public perceptions of science'.»

In the same commentary, it is outlined by this author how this promising setup can prove useful if researchers overcome certain hurdles. *First*, they need to agree on a common set of items and make sure all surveys implement or update them accordingly. *Second*, analyses need to strive towards more robust solutions by comparing across methods, particularly by favouring methods with fewer researcher degrees of freedom in their analytical steps (e.g. latent class analysis). *Third*, transparency should be elevated to allow researchers to replicate and re-apply segment-solutions to new data sets independently. This too is more achievable if researchers use model-based methods like latent class analysis.

If these preconditions are met, researchers could apply the Audience Perspective Framework (see 2.2.3) and systematically vary certain context factors while keeping other factors constant. For example, analyses could focus on issue-based factors by choosing a single issue and gather survey data over time with the aim of capturing different periods within the issue-cycle. Or, they could survey people about an issue when it is not politicised and survey them about the same issue again if and when it becomes more politicised. Focusing on media-based factors, e.g. comparing multiple populations within different media systems, could also yield interesting insights, while a focus on people-based factors could result in cross-national and long-term analyses.

Long-term analyses would be interesting to monitor whether certain issue-specific audiences develop characteristics of echo chambers or social polarization. So far, science communication researchers have not studied these two phenomena as much (Metag & Schäfer, 2018; Scheufele & Krause, 2019). For example, it would be interesting to monitor how the German climate change segments in Metag et al. (2015) alter over time. If extreme groups like the «Alarmed» and the «Doubtful» were to grow, this could be a sign of social polarisation. If segments became more homogenous and unvaried in their media use behaviour, concerns about echo chambers might be warranted.

There are many ways to approach such systematic segmentation analyses: Researchers can segment each data set individually, as in Metag et al. (2018) for Switzerland and Germany. Another option is to combine data sets from different countries to find one overarching solution and assess how the different populations are represented in these groups. A third way is to find a solution in one data set and re-apply the same solution to a new data set (e.g. for another country or year) and assess how the subjects in the new data set are grouped together (e.g. Mark Morrison, Parton, & Hine, 2018). Scholars may combine or modify these approaches. For example, they can run a fresh segmentation analysis and compare it with the results of an already existing solution applied to the same data set.

In climate change communication, the reproduction of existing solutions is a common approach. For example, Maibach et al. (2011) provided the statistical model of their solution, which was applied by other researchers overseas and over a number of years (e.g. Detenber, Rosenthal, Liao, & Ho, 2016; M. Morrison, Duncan, Sherley, & Parton, 2013). This approach is challenging as researchers need identical variables in their new data to re-apply an existing solution. The Maibach et al. (2011) solution consists of 36 variables, meaning that other researchers need considerable survey resources to re-apply the original solution.

One way of dealing with this problem is to create a short scale. Short scales of segmentation analyses are a more efficient although less precise way of applying a segment-solution, i.e. the logic of sorting cases into different groups, to a new data set. What is ‘short’ is the number of items necessary to reconstruct a very similar solution. Creating a short scale hinges on identifying the most discriminant items when attributing cases to their groups. For latent class analyses, this leads to a prediction model that uses fewer independent variables.

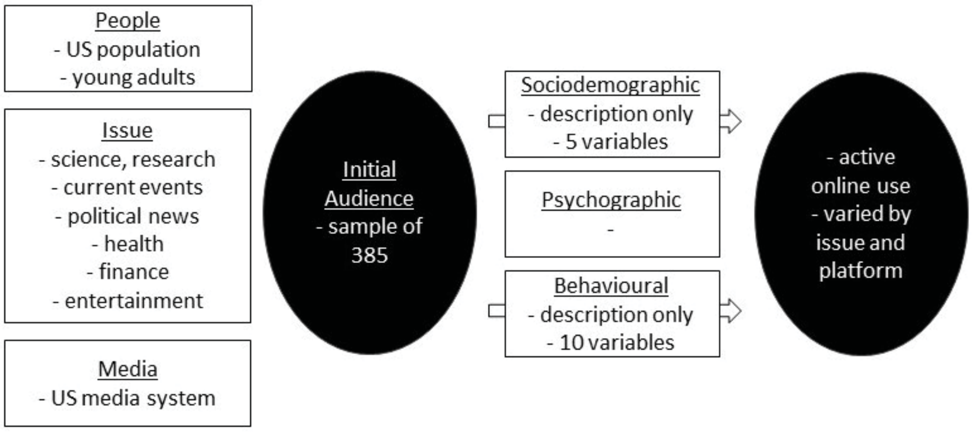
To facilitate systematic efforts in science communication, we proposed a short scale for the Schäfer, Füchslin et al. (2018) segmentation (see 7.6). The original solution consists of twenty variables. We were able to identify the ten most important predictors and show that they can still correctly attribute over 90% of cases to the same clusters. Additionally, the clusters based on the short scale lead to the same results as the clusters based on the full scale when using cluster membership to predict science-related behaviours.

With the capacity to access a solution by using fewer variables it is achievable that other researchers can implement this in smaller surveys and see predictions in data sets from different contexts. Additionally, over time, researchers can potentially agree on a small but crucial set of variables in science communication. Such a set of variables would be worth incorporating in national surveys (Füchslin, 2019).

3.3 Theoretical Advances Through an Audience Perspective

An audience perspective can also provide theoretical advances. On the one hand, it can give direct insight overlooked phenomena and a subsequent research agenda. This is exemplified in Hargittai, Füchslin, and Schäfer (2018), where we analyse science content and its relevance in young adults' social media use in the United States, an audience context that has not yet received sufficient scholarly attention (see 7.7). People-based factors describe a context of college-educated young adults (aged around 25) in the US, all originating from an earlier survey that took place in a college class. The data is not representative but was shown to be valuable for digital media research in the past. Media-based factors set parameters, namely that the focus is on people's social media use (i.e. Twitter, Facebook and email). In terms of issue-based factors, the analysis focused on science and research as the primary issue in comparison with other news media issues like health, current events, and entertainment. The initial audience consisted of 385 people and was not constructed further into any sub-audiences. Instead, we described the initial audience in terms of behavioural variables, i.e. its frequency of using Twitter, Facebook and email, as well as frequencies of clicking on, sharing, and commenting on content on these platforms. As a result, we were able to characterise these young adults as a collective audience with certain overall media use behaviours (Figure 10).

Figure 10: Hargittai et al. (2018) within the Audience Perspective Framework



As the focus on behavioural variables suggest, this audience was conceived as potentially active online users. The study demonstrated that young adults surprisingly often engage with scientific content on social media, that there are considerable differences between platforms, and that sharing is less common than clicking and commenting, particularly on Twitter. While this study was not conducted to provide generalisable insights about social media use frequencies of young adults, it indicated the relevance of science-related content by contrasting various news media issues, and highlighted additional nuances in platform and behavioural differences. These insights are not practical but valuable for any future studies when conceptualising important aspects of young adults' social media use. Additionally, they encourage additional research into a previously overlooked topic.

On the other hand, audience research with systematic segmentation efforts can indirectly lead to theoretical insights, and even full theoretical frameworks, which are needed in present science communication research (Scheufele, 2018), and is rare in climate change communication (Hine et al., 2014). Füchslin (2019) discussed this scenario: systematic segmentation efforts require researchers to recognise what dimensions are most relevant for segmentation and agree on a common set of variables. Consequently, researchers will prioritise theoretical groundwork in an attempt to find a concise theoretical framework.

Such groundwork can take advantage of empirical insights. Testing potential theoretical frameworks on varying data sets can falsify imperfect frameworks and eventually lead to well-specified frameworks. This would also solve current discussions in climate change communication, where Hine et al. (2014) contend that climate change segmentations should also include variables that are not directly related to the issue of climate change, but also cover more general values.

4 Additional Aspects of an Audience Perspective in Science Communication

The Audience Perspective Framework suggests a research approach that highlights contextual factors and emphasises an audience construction process based on three categories of audience-related variables. It leads to a static conception of audiences, which fails to consider how audiences interpret information and messages. Due to the complexity of scientific information, it is often challenging to understand, therefore individuals tend to process it heuristically (Druckman & Lupia, 2017). Research in (media) psychology has discovered a number of cognitive tendencies and effects relevant to science communication which should be considered within an audience perspective (for an overview, see Jamieson et al., 2017, Part 6).

Motivated reasoning is arguably the most relevant cognitive processes in science communication (Scheufele, 2014; Scheufele & Krause, 2019). It describes how people's motives influence the way they process information, i.e. (re)forming impressions, beliefs, and attitudes, as well as evaluating evidence, and making decisions (Kunda, 1990). If people are motivated by so-called «accuracy goals», they are more likely to evaluate information and weigh arguments against each other carefully. If they have «directional goals», they are prone to confirmation bias, i.e. to process information in a way that is biased towards their prior attitudes, beliefs, and values. People rarely have true accuracy goals and tend to be strongly biased by their predispositions (Suhay, Druckman, Kraft, Lodge, & Taber, 2015). This seems to be particularly true in the context of socio-scientific issues. Studies showed that these variables are strong predictors of how people interpret the same information on topics such as climate change (Hart & Nisbet, 2011) and emerging technologies like carbon nanotubes and genetically modified foods (Druckman & Bolsen, 2011). Having 'higher' knowledge does not change this tendency. Drummond and Fischhoff (2017) confirmed value-based polarisation of attitudes towards six socio-scientific issues and additionally showed that people with high levels of scientific construct and process knowledge displayed even more polarised attitudes.

Studies suggest that motivated reasoning leads to selective exposure (Scheufele & Krause, 2019), which describes how people tend to choose belief-consistent information over belief-inconsistent information (Redlawsk, 2002). Simulating online content selection, Yeo, Xenos, Brossard, and Scheufele (2015) showed that people are more likely to choose partisan information when they are unsure where on the political spectrum the issue of interest falls.

Metzger, Flanagin, and Medders (2010) described the «expectancy violation heuristic», which outlines how users reject websites that offer content that is not in line with their prior beliefs. In the online health domain, studies also find evidence for attitude-consistent information selection (e.g. Hastall & Wagner, 2017).

Kovic and Füchslin (2018) have contributed to the literature on cognitive processes through examination of people's perception of rare events, such as the 9/11 attacks, which some perceived as a conspiracy (see 7.8). We ran a series of online experiments; each exposed participants to a text describing a real-life scenario (e.g. a famous journalist was found dead in his apartment). The description gave participants in separate experimental groups different information of the scenario's likelihood according to experts (e.g. medical examiners saying the journalist was 90% likely to die of a heart attack). After reading the scenario, we asked participants to assess the likelihood of the straightforward explanations of the event being correct (e.g. the journalist died of a heart attack), compared to the likelihood of a conspiratorial explanation (e.g. the journalist was murdered) being the true reason. As we hypothesised, we found a clear and linear effect showing that the more unlikely an event, the more people are willing to entertain conspiratorial explanations.

This finding also has implications for our understanding of audiences in science communication. Particularly for rare and extraordinary events such as Neil Armstrong landing on the moon in 1969 or Philae landing on a moving comet in 2014, it is important to consider that such events may not only induce awe but will always raise some suspicion. Beyond the fact that this effect is the same between across genders, we do not know yet, whether some audiences might be more prone to interpreting rare events in conspiratorial fashion.

When designing effective science communication, these cognitive tendencies are important because they lead to different effects on audiences. Scientific information is often multifaceted and needs to be condensed when communicated. This compression can put an emphasis on differing aspects of the phenomenon (often described as framing), leading to different communication effects (Druckman & Lupia, 2017). Research investigates the overall effects of different message designs and frames in science communication. This leads to general findings such as the conclusion that adding images to blog posts not only increases readers enjoyment but also their recall of the text's content (Gardiner, Sullivan, & Grand, 2018), and that mentioning a clear scientific consensus induces people to assess content more substantially rather than following other heuristics such as political cues (Bolsen & Druckman, 2015).

In a visual framing study, Metag, Schäfer, Füchslin, Barsuhn, and Kleinen-von Königslöw (2016) investigated effects of climate change imagery on people's perceptions in Switzerland, Germany, and Austria (see 7.9). We showed 75 people (25 per country) 40 images related to climate change and asked whether the images made them feel that climate change is an important issue (*salience*) and whether they made them feel that they can do something about global warming (*self-efficacy*). Subjects answered these two questions by arranging all images on a pyramid-shaped sorting grid, which represented a continuum from left (lowest salience/self-efficacy) to right (highest salience/self-efficacy). The pyramid layout meant that people could only choose a few images that evoked very high/ low salience or self-efficacy. We analysed the placements and found that particularly images of climate change impacts (e.g. flooded areas) in particular made people feel that climate change is an important issue, while pictures of renewable energy systems (e.g. solar panels) and consumption habits (e.g. a meat counter) left people feeling most empowered to act. These findings were mostly stable across all three countries and mirrored findings from a similar study with participants from the US, UK and Australia (S. J. O'Neill, Boykoff, Niemeyer, & Day, 2013).

Such insights into how people perceive information and messages can inform the way we address different audiences. For example, our study suggests that images of renewable energy systems like solar panels would be a well-informed choice when encouraging people to reduce their carbon footprint (Metag et al., 2016). Another study would suggests that the message itself could emphasize how many people are already using solar panels, taking advantage of the powerful influence of social norms (Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007).

These insights, however, pertain to undifferentiated audiences. Scholars have referenced that, ideally, we would be able to expand this knowledge with more specific knowledge about different types of audiences (M. C. Nisbet & Scheufele, 2009). For example, it would be interesting to know, whether perceptions of climate change images vary between people from different climate change segments like the «Alarmed» and the «Doubtful» in Germany (Metag et al., 2015). The few studies that have tried to combine message design with audience-specific characteristics mostly looked at simple audience constructs. For example, a US study constructed its audiences through the partisan lens and investigated the effect of slightly altered endorsements for a science policy on Democrats and Republicans. The study found that mentioning one party as the main endorser of the policy leads both Democrats and Republicans to engage in motivated reasoning, assessing the policy in line with their ideology (Bolsen, Toby and Druckman, James N. and Cook, Fay Lomax, 2014). This differentiation of two political audiences exemplifies the power of designing tailored messages design: both groups can be nudged towards supporting the policy, simply by naming their party as the prime endorser, regardless of the actual policy content. There are certainly moral issues that accompany the alteration of facts in messages. Nonetheless, it would be interesting to extend this approach to more complex audience constructs. Using results from more sophisticated segmentation analyses such as Schäfer, Füchslin et al. (2018) and conducting experiments that account for different group membership would be an ideal step to advance our understanding of different audiences.

5 Conclusion

Science communication research is relevant and thriving. However, the field would benefit from practical insights, theoretical advances, systematic and long-term analyses, insights beyond Anglophone countries, and research on different audiences. I outlined and exemplified how science communication research can use an audience perspective not only to build on existing research on different audiences but to stimulate answers to the other challenges as well. Building on (science communication) literature on audience research, I proposed the Audience Perspective Framework: a framework that guides analyses with an audience perspective in science communication. I presented four empirical segmentation analyses via the framework (i.e. Füchslin et al., 2019; Metag et al., 2015; Metag et al., 2018; Schäfer, Füchslin et al., 2018), outlining how cluster analyses are a relevant method that can provide practical insights for the «Science of Science Communication» (Jamieson, 2017). These findings increase our overall understanding of different audiences, whilst providing insights into Switzerland and Germany, two non-Anglophone countries. I also showed how the field of science communication has the resources to facilitate an increase in systematic analyses of different audiences (Füchslin, 2019). Segmentation analyses can systematically vary people-, media-, and issue-based context factors within the Audience Perspective Framework and take advantage of tools such as our recently developed short scale (Füchslin, Schäfer, & Metag, 2018). Long-term analyses, in particular, could shed light on issues such as potential echo chambers and social polarization (Metag & Schäfer, 2018; Scheufele & Krause, 2019). To reinforce the benefits of an audience perspective, I exemplified how sample descriptions of interesting audiences can shape research agendas and foci (Hargittai et al., 2018), and how systematic segmentation efforts can indirectly lead to new theoretical frameworks in science communication (Füchslin, 2019). I also discussed how insights into people's general perceptions of information and messages enhance our understanding of audiences and that these findings could be expanded through differentiating them across various audiences.

While the text presents an audience perspective as highly beneficial to science communication, my arguments come with some limitations. *First*, I employ a wide understanding of the «audience perspective». If we apply the 'Lasswellian' separation of the communication process, the audience perspective covers three of the five steps in the communication process: the recipients, channels and effects. I invoke this when directly analysing audiences via segmentation analyses, but also applied the audience perspective to overall sample descriptions and a media effects study. Furthermore, different media channels also play an indirect role as context factors and variables. Only the two steps of communicators and content are, therefore, not included in my understanding of the perspective.

Second, I do not define audiences themselves in the text. My argument builds on readers' lay understanding of the term, instead highlighting important properties of audiences such as their constructed and contextual character. While it would have been interesting to propose a substantial definition, there are understandable reasons why such definitions are mostly absent from current literature. Audiences are such context-dependent constructs that only generic definitions make sense. These, again, do not substantively contribute to people's intuitive understanding of audiences. I would also contend that the main arguments of the text did not necessitate such a definition.

Third, the proposed Audience Perspective Framework is only heuristic. It neither provides a comprehensive list of contextual factors nor audience construction variables. It is an analytical tool that highlights the most important aspects required when researching audiences such as thinking about the role of specific issues and differentiating between context and additional audience construction. It would be beneficial to the field to build on this framework and make it more comprehensive. On top of that, it would be beneficial to add a whole section for communication effects on different audiences, as touched upon in section 4.

Fourth, the studies themselves for the most part did mostly not have practical goals, even though they were used to demonstrate practical benefits. The four segmentation analyses advanced our general understanding of different populations, providing tangible collective audience constructs, and building a basis for future research. Three analyses purely focused on the issue of «science and research», which is vague and limits practical applications (Burns & Medvecky, 2018). As such, they did not investigate any messages tailored to different audiences. Combining effects studies with constructions of different audiences would be the most efficient way of highlighting the practical value of an audience perspective. Such efforts would also shed light on actual effect sizes and, therefore, on the actual practical value of audience segmentations.

Fifth, it was only possible within the remit to give a basic premise as to how an audience perspective would help to increase the number of systematic analyses and new theoretical frameworks. This argument is primarily based on my commentary article (Füchslin, 2019), which did not go beyond a prospective level. Having examples of systematic analyses or theoretical frameworks within my own body of work would have been a valuable addition. This represents one of the most interesting research gaps for science communication research with an audience perspective.

Sixth, it was only possible psychological processes and their effects on audiences briefly. Nevertheless, these processes are integral for an audience perspective; simply constructing audiences is futile in the absence of a goal to provoke reactions through communication efforts at some point.

Looking at the individual studies, there are issues with the four segmentation analyses. They do not follow a theoretical model in their variable selection. As a result, we never faced theoretical decisions such as whether to include basic dimensions like people's overall values (Hine et al., 2014). We employed dimensions established in related research on science and society or climate change communication. We often represented these dimensions through single items, which lessens the measurements' reliability (Hine et al., 2014). Reliability might also be built on imperfect validity since the data consist of self-assessed survey items. If these limitations are considered alongside the application of a short scale that is 90% reliable and that was only tested within its original sample, segmentation results should be interpreted with caution. As a result, it is even more important not to overemphasise the resulting segments but rather see them as a heuristic tool for practical communication efforts.

When researching audiences, the sampling process is crucial as it shapes what the initial audience represents. Five of the eight empirical studies were based on nationally representative probability samples. These findings could be improved by replicating analyses on newer data sets such as replicating Schäfer, Füchslin et al. (2018) with the new Science Barometer 2019 data. The other studies did not use representative samples. For Kovic and Füchslin (2018) this was not as problematic because it found a very robust effect and investigated a cognitive process, which is likely to be universal. For Hargittai et al. (2018) and Metag et al. (2016) the findings would have benefitted from the samples being more representative of their inferred audiences, e.g. young adults in the US and people in Switzerland, Germany and Austria.

Despite these shortcomings, the benefits of an audience perspective in science communication remain strong and are awaiting future research. As aforementioned, the most interesting avenues are systematic analyses, particularly through segmentation analyses. It would be interesting for researchers to employ a framework like the Audience Perspective Framework to vary context factors systematically while focusing on a theoretically relevant set of cluster-variables. Additionally, established segment-solutions can always be incorporated in effects studies that bring us deeper comprehension of how different audiences think and react to different messages. Such efforts would maintain the relevancy of and success in science communication research whilst providing practical results for science communicators trying to uphold science's rightful presence in everyday life.

6 References

Allor, M. (1988). Relocating the site of the audience. *Critical Studies in Mass Communication*, *5*(3), 217–233. https://doi.org/10.1080/15295038809366704

Anderson, A. A., Brossard, D., Scheufele, D. A., Xenos, M. A., & Ladwig, P. (2014). The "Nasty Effect:" Online Incivility and Risk Perceptions of Emerging Technologies. *Journal of Computer-Mediated Communication*, *19*(3), 373–387. https://doi.org/10.1111/jcc4.12009

Ang, I. (1991). *Desperately seeking the audience*. London, New York: Routledge. Retrieved from http://site.ebrary.com/lib/academiccompletetitles/home.action

Barberá, P., Jost, J. T., Nagler, J., Tucker, J. A., & Bonneau, R. (2015). Tweeting From Left to Right: Is Online Political Communication More Than an Echo Chamber? *Psychological Science*, *26*(10), 1531–1542. https://doi.org/10.1177/0956797615594620

Bauer, M. W. (2012). Public Attention to Science 1820-2010 - A 'Longue Durée' Picture. In Rödder, Simone and Franzen, Martina and Weingart, Peter (Ed.), *The Sciences' Media Connection - Public Communication and its Repercussions* (pp. 35–57). Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-007-2085-5_3

Bauer, M. W., Allum, N., & Miller, S. (2007). What can we learn from 25 years of PUS survey research? Liberating and expanding the agenda. *Public Understanding of Science*, *16*(1), 79–95. https://doi.org/10.1177/0963662506071287

Bauer, M. W., & Gregory, J. (2008). From journalism to corporate communication in post-war Britain. In M. W. Bauer & M. Bucchi (Eds.), *Journalism, Science and Society: Science Communication between News and Public Relations* (pp. 33–52). Taylor & Francis.

Bensaude-Vincent, B. (2001). A genealogy of the increasing gap between science and the public, *10*(1), 99–113.

Besley, J. C., & Nisbet, M. (2013). How scientists view the public, the media and the political process. *Public Understanding of Science (Bristol, England)*, *22*(6), 644–659. https://doi.org/10.1177/0963662511418743

Bird, S. E. (2003). *The audience in everyday life: Living in a Media World*. New York: Routledge. Retrieved from http://www.loc.gov/catdir/enhancements/fy0651/2003011583-d.html

Blok, A., Jensen, M., & Kaltoft, P. (2008). Social identities and risk: expert and lay imaginations on pesticide use. *Public Understanding of Science*, *17*(2), 189–209. https://doi.org/10.1177/0963662506070176

Blue, G. (2010). Food, publics, science. *Public Understanding of Science (Bristol, England)*, *19*(2), 147–154. https://doi.org/10.1177/0963662508098575

Bolsen, T., & Druckman, J. N. (2015). Counteracting the Politicization of Science. *Journal of Communication*, *65*(5), 745–769. https://doi.org/10.1111/jcom.12171

Bolsen, Toby and Druckman, James N. and Cook, Fay Lomax (2014). The Influence of Partisan Motivated Reasoning on Public Opinion. *Political Behavior*, *36*(2), 235–262. https://doi.org/10.1007/s11109-013-9238-0

Bonfadelli, H. (2017). Handlungstheoretische Perspektiven auf die Wissenschaftskommunikation. In H. Bonfadelli, B. Fähnrich, C. Lüthje, J. Milde, M. Rhomberg, & M. S. Schäfer (Eds.), *Forschungsfeld Wissenschaftskommunikation* (pp. 83–105). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-12898-2_5

Bonfadelli, H., Fähnrich, B., Lüthje, C., Milde, J., Rhomberg, M., & Schäfer, M. S. (2017). Das Forschungsfeld Wissenschaftskommunikation. In H. Bonfadelli, B. Fähnrich, C. Lüthje, J. Milde, M. Rhomberg, & M. S. Schäfer (Eds.), *Forschungsfeld Wissenschaftskommunikation* (pp. 3–14). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-12898-2_1

Brossard, D. (2013). New media landscapes and the science information consumer. *Proceedings of the National Academy of Sciences of the United States of America*, *110 Suppl 3*, 14096–14101. https://doi.org/10.1073/pnas.1212744110

Brossard, D., & Scheufele, D. A. (2013). Science, New Media, and the Public. *Science (New York, N.Y.)*, *339*(6115), 40–41. https://doi.org/10.1126/science.1232329

Bruns, A. (2008). *Blogs, Wikipedia, Second Life, and beyond: From production to produsage* (Vol. 45): Peter Lang.

Bubela, T., Nisbet, M. C., Borchelt, R., Brunger, F., Critchley, C., Einsiedel, E., . . . Caulfield, T. (2009). Science communication reconsidered. *Nature Biotechnology*, *27*(6), 514–518. https://doi.org/10.1038/nbt0609-514

Bucchi, M. (2017). Credibility, expertise and the challenges of science communication 2.0. *Public Understanding of Science (Bristol, England)*, *26*(8), 890–893. https://doi.org/10.1177/0963662517733368

Bucchi, M., & Trench, B. (2014). Science communication research: themes and challanges. In M. Bucchi & B. Trench (Eds.), *Routledge Handbook of Public Communication of Science and Technology: Second edition* (pp. 1–14). London: Routledge.

Büchi, M. (2017). Microblogging as an extension of science reporting. *Public Understanding of Science (Bristol, England)*, *26*(8), 953–968. https://doi.org/10.1177/0963662516657794

Burchell, K. (2018). *Public Attitudes to Science 2018: Literature review.*

Burningham, K., Barnett, J., Carr, A., Clift, R., & Wehrmeyer, W. (2007). Industrial constructions of publics and public knowledge: a qualitative investigation of practice in the UK chemicals industry. *Public Understanding of Science*, *16*(1), 23–43. https://doi.org/10.1177/0963662506071285

Burns, M., & Medvecky, F. (2018). The disengaged in science communication: How not to count audiences and publics. *Public Understanding of Science (Bristol, England)*, *27*(2), 118–130. https://doi.org/10.1177/0963662516678351

Butsch, R. (2011). Audiences and Publics, Media and Public Spheres. In V. Nightingale (Ed.), *The Handbook of Media Audiences* (pp. 149–168). Wiley.

Carpentier, N. (2011). New Configurations of the Audience?: The Challenges of User-Generated Content for Audience Theory and Media Participation. In V. Nightingale (Ed.), *The Handbook of Media Audiences* (pp. 190–212). Wiley.

CDC (2019, January 1). Media Library of Immunization PSAs | CDC. Retrieved from https://www.cdc.gov/ncird/media/resources/index.html

Chaffee, S. H., & Metzger, M. J. (2001). The End of Mass Communication? *Mass Communication and Society*, *4*(4), 365–379. https://doi.org/10.1207/S15327825MCS0404_3

Chapman, C., & Feit, E. M. (2019). *R For Marketing Research and Analytics* (2nd ed. 2019). *Use R!* https://doi.org/10.1007/978-3-030-14316-9

Cornell University, INSEAD, and WIPO (2019). *The Global Innovation Index 2019*. Ithaca, Fontainebleau, and Geneva.

Dawson, E. (2018). Reimagining publics and (non)participation: Exploring exclusion from science communication through the experiences of low-income, minority ethnic groups. *Public Understanding of Science (Bristol, England)*, 963662517750072. https://doi.org/10.1177/0963662517750072

Detenber, B. H., Rosenthal, S., Liao, Y., & Ho, S. S. (2016). Audience Segmentation for Campaign Design: Addressing Climate Change in Singapore. *International Journal of Communication*. (10), 4736–4758. Retrieved from https://dr.ntu.edu.sg/bitstream/10220/41984/1/4696-22462-1-PB.pdf

Dingerkus, F., Keel, G., & Wyss, V. (2016). *Country Report: Journalists in Switzerland.* https://doi.org/10.5282/UBM/EPUB.30991

Druckman, J. N., & Bolsen, T. (2011). Framing, Motivated Reasoning, and Opinions About Emergent Technologies. *Journal of Communication*, *61*(4), 659–688. https://doi.org/10.1111/j.1460-2466.2011.01562.x

Druckman, J. N., & Lupia, A. (2017). Using Frames to make Scientific Communication More Effective. In K. H. Jamieson, D. M. Kahan, D. A. Scheufele, & M. S. Schäfer (Eds.), *The Oxford Handbook of The Science of Science Communication.* Oxford University Press.

Drummond, C., & Fischhoff, B. (2017). Individuals with greater science literacy and education have more polarized beliefs on controversial science topics. *Proceedings of the National Academy of Sciences of the United States of America.* Advance online publication. https://doi.org/10.1073/pnas.1704882114

Dunwoody, S. (2014). Science journalism: prospects in the digital age. In M. Bucchi & B. Trench (Eds.), *Routledge Handbook of Public Communication of Science and Technology: Second edition* (pp. 27–39). London: Routledge.

Einsiedel, E. (2000). Understanding "Publics" in the Public Understanding of Science. In M. Dierkes & C. von Grote (Eds.), *Between understanding and trust: The public, science and technology* (pp. 205–215). Australia: Harwood Academic Publishers.

Einsiedel, E. (2007). Editorial: Of publics and science. *Public Understanding of Science*, *16*(1), 5–6. https://doi.org/10.1177/0963662506071289

Eisenegger, M., & Gedamke, S. (2013). Wissenschaft in Medien: Zur Logik medialer Wissenschaftsthematisierung. *medien & zeit*, *28*(4), 34–44.

Eurobarometer (2010). *Special Eurobarometer 340: Science and Technology.*

Featherstone, H., Weitkamp, E., Ling, K., & Burnet, F. (2009). Defining issue-based publics for public engagement: Climate change as a case study. *Public Understanding of Science (Bristol, England)*, *18*(2), 214–228. https://doi.org/10.1177/0963662507082890

Felt, U. (2000). Why Should the Public "Understand" Science?: A Historical Perspective on Aspects of the Public Understanding of Science. In M. Dierkes & C. von Grote (Eds.), *Between understanding and trust: The public, science and technology* (pp. 7–38). Australia: Harwood Academic Publishers.

Fischhoff, B. (2013). The sciences of science communication. *Proceedings of the National Academy of Sciences of the United States of America*, *110 Suppl 3*, 14033–14039. https://doi.org/10.1073/pnas.1213273110

Fiske, J. (1992). Audiencing: A cultural studies approach to watching television. *Poetics*, *21*(4), 345–359. https://doi.org/10.1016/0304-422X(92)90013-S

Fög (2017). *Jahrbuch 2017: Qualität der Medien*. Zürich.

Füchslin, T. (2016). What are you folding for? Nutzungsmotivationen von -Citizen Science Online Games und ihre -Lerneffekte. *merzWissenschaft*, *60*(6), 110–122.

Füchslin, T. (2019). Science communication scholars use more and more segmentation analyses: Can we take them to the next level? *Public Understanding of Science (Bristol, England)*, *28*(7), 854-864. https://doi.org/10.1177/0963662519850086

Füchslin, T., Schäfer, M. S., & Metag, J. (2018). A Short Survey Instrument to Segment Populations According to Their Attitudes Toward Science. Scale Development, Optimization and Assessment. *Environmental Communication*, *12*(8), 1095–1108. https://doi.org/10.1080/17524032.2018.1461673

Füchslin, T., Schäfer, M. S., & Metag, J. (2019). Who wants to be a citizen scientist? Identifying the potential of citizen science and target segments in Switzerland. *Public Understanding of Science (Bristol, England)*, *28*(6), 652-668. https://doi.org/10.1177/0963662519852020

Funtowicz, S. O., & Ravetz, J. R. (1985). Three types of risk assessment: a methodological analysis. In *Environmental impact assessment, technology assessment, and risk analysis* (pp. 831–848). Springer.

Fürst, S. (2014). „The audience is the message“: Die journalistische Berichterstattung über Publikumsresonanz. In Loosen, Wiebke and Dohle, Marco (Ed.), *Journalismus und (sein) Publikum: Schnittstellen zwischen Journalismusforschung und Rezeptions- und Wirkungsforschung* (pp. 131–149). Wiesbaden: Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-531-19821-7_8

Gardiner, A., Sullivan, M., & Grand, A. (2018). Who Are You Writing for? Differences in Response to Blog Design Between Scientists and Nonscientists. *Science Communication*, *40*(1), 109–123. https://doi.org/10.1177/1075547017747608

Garrett, R. K. (2017). The “Echo Chamber” Distraction: Disinformation Campaigns are the Problem, Not Audience Fragmentation. *Journal of Applied Research in Memory and Cognition*, *6*(4), 370–376. https://doi.org/10.1016/j.jarmac.2017.09.011

Gregory, J., & Miller, S. (1998). *Science in public: Communication, culture, and credibility*: Plenum Press.

Grunig, J. E., & Hunt, T. T. (1984). *Managing public relations*. San Diego, CA: Harcourt Brace Jovanovich College Publishers.

Guenther, L., & Joubert, M. (2017). Science communication as a field of research: identifying trends, challenges and gaps by analysing research papers. *Journal of Science Communication*, *16*(02). https://doi.org/10.22323/2.16020202

Hall, S. (2001). Encoding/decoding. *Media and cultural studies: Keyworks*, *2*.

Hallin, D. C., & Mancini, P. (2004). *Comparing media systems: Three models of media and politics*: Cambridge University Press.

Hargittai, E., Füchslin, T., & Schäfer, M. S. (2018). How Do Young Adults Engage With Science and Research on Social Media? Some Preliminary Findings and an Agenda for Future Research. *Social Media + Society*, *4*(3), 205630511879772. https://doi.org/10.1177/2056305118797720

Hart, P. S., & Nisbet, E. C. (2011). Boomerang Effects in Science Communication. *Communication Research*, *39*(6), 701–723. https://doi.org/10.1177/0093650211416646

Hasebrink, U. (2008). Das multiple Publikum: Paradoxien im Verhältnis von Journalismus und Mediennutzung. In Pörksen, Bernhard and Loosen, Wiebke and Scholl, Armin (Ed.), *Paradoxien des Journalismus: Theorie -- Empirie -- Praxis Festschrift für Siegfried Weischenberg* (pp. 513–530). Wiesbaden: VS Verlag für Sozialwissenschaften. https://doi.org/10.1007/978-3-531-91816-7_29

Hastall, M. R., & Wagner, A. J. M. (2017). Enhancing Selective Exposure to Health Messages and Health Intentions. *Journal of Media Psychology*, 1–15. https://doi.org/10.1027/1864-1105/a000197

Hine, D. W., Reser, J. P., Morrison, M. [Mark], Phillips, W. J., Nunn, P., & Cooksey, R. (2014). Audience segmentation and climate change communication: Conceptual and methodological considerations. *Wiley Interdisciplinary Reviews: Climate Change*, *5*(4), 441–459. https://doi.org/10.1002/wcc.279

Ipsos MORI (2011). *Public Attitudes to Science 2011: Main Report*. Retrieved from https://www.ipsos.com/ipsos-mori/en-uk/public-attitudes-science-2011

Irwin, A., & Michael, M. (2003). *Science, social theory and public knowledge*. Maidenhead: Open University Press.

Jamieson, K. H. (2017). The Need for a Science of Science Communication: Communicating Science's Values and Norms. In K. H. Jamieson, D. M. Kahan, D. A. Scheufele, & M. S. Schäfer (Eds.), *The Oxford Handbook of The Science of Science Communication* (pp. 15–24). Oxford University Press.

Jamieson, K. H., & Cappella, J. N. (2008). *Echo chamber: Rush Limbaugh and the conservative media establishment*: Oxford University Press.

Jamieson, K. H., Kahan, D. M., Scheufele, D. A., & Schäfer, M. S. (Eds.). (2017). *The Oxford Handbook of The Science of Science Communication* (Vol. 1): Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190497620.013.5

Jasanoff, S. (2014). A mirror for science. *Public Understanding of Science (Bristol, England)*, *23*(1), 21–26. https://doi.org/10.1177/0963662513505509

Kawamoto, S., Nakayama, M., & Saijo, M. (2011). A survey of scientific literacy to provide a foundation for designing science communication in Japan. *Public Understanding of Science (Bristol, England)*, *22*(6), 674–690. https://doi.org/10.1177/0963662511418893

Koch, C., Schäfer, M. S., Hermann-Giovanelli, I., Saner, M., & Metag, J. (forthcoming). 'Space means science, unless it's about Star Wars': A Qualitative Assessment of Audience Segments. *Public Understanding of Science*, 1–24.

Kovic, M., & Füchslin, T. (2018). Probability and conspiratorial thinking. *Applied Cognitive Psychology*, *32*(3), 390–400. https://doi.org/10.1002/acp.3408

Kristiansen, S., Schäfer, M. S., & Lorencez, S. (2016). Science journalists in Switzerland: Results from a survey on professional goals, working conditions, and current changes. *Studies in Communication Sciences*, *16*(2), 132–140. https://doi.org/10.1016/j.scoms.2016.10.004

Kunda, Z. (1990). The case for motivated reasoning. *Psychological bulletin*, *108*(3), 480.

Künzler, M. (2013). *Mediensystem Schweiz*. *Kommunikationswissenschaft*. Konstanz: UVK Verlagsgesellschaft. Retrieved from https://www.content-select.com/index.php?id=bib_view&ean=9783864961748

Laclau, E. (2005). *On Populist Reason*: Verso. Retrieved from https://books.google.ch/books?id=_LBBy0DjC4gC

Landrum, A. R. (2017). A Recap–The Role of Intermediaries in Communicating Science: A Synthesis. In K. H. Jamieson, D. M. Kahan, D. A. Scheufele, & M. S. Schäfer (Eds.), *The Oxford Handbook of The Science of Science Communication* (pp. 253–258). Oxford University Press.

Langeheine, R., & Rost, J. (Eds.). (2013). *Latent trait and latent class models* ([Reprinted]). New York, NY: Springer Science+Business Media.

Lewandowsky, S., Ecker, U. K.H., & Cook, J. (2017). Beyond Misinformation: Understanding and Coping with the "Post-Truth" Era. *Journal of Applied Research in Memory and Cognition*, *6*(4), 353–369. https://doi.org/10.1016/j.jarmac.2017.07.008

Lewenstein, B. V. (2002). Editorial: A decade of Public Understanding, *11*(1), 1–4.

Livingstone, S. (2013). The Participation Paradigm in Audience Research. *The Communication Review*, *16*(1-2), 21–30. https://doi.org/10.1080/10714421.2013.757174

Maibach, E. W., Leiserowitz, A., Roser-Renouf, C., & Mertz, C. K. (2011). Identifying like-minded audiences for global warming public engagement campaigns: An audience segmentation analysis and tool development. *PloS One*, *6*(3), e17571. https://doi.org/10.1371/journal.pone.0017571

Maletzke, G. (1963). *Psychologie der Massenkommunikation: Theorie und Systematik*. Hamburg: Hans Bredow-Institut.

Mangold, F., Vogelgesang, J., & Scharkow, M. (2017). Nachrichtennutzung in Deutschland. Eine nutzerzentrierte Repertoireanalyse. *Medien & Kommunikationswissenschaft*, *65*(4), 704–723. https://doi.org/10.5771/1615-634X-2017-4-704

McQuail, D. (1994). *Mass communication theory: An introduction* (3. ed., reprinted.). London: Sage Publ. Retrieved from http://www.loc.gov/catdir/enhancements/fy0656/94065489-d.html

Meja, V., & Stehr, N. (2017). *Society & Knowledge*: Routledge. https://doi.org/10.4324/9781315129884

Mejlgaard, N. (2018). Science's disparate responsibilities: Patterns across European countries. *Public Understanding of Science (Bristol, England)*, *27*(3), 262–275. https://doi.org/10.1177/0963662517724645

Metag, J., Füchslin, T., & Schäfer, M. S. (2015). Global warming's five Germanys: A typology of Germans' views on climate change and patterns of media use and information. *Public Understanding of Science (Bristol, England)*, *26*(4), 434–451. https://doi.org/10.1177/0963662515592558

Metag, J., Maier, M., Füchslin, T., Bromme, L., & Schäfer, M. S. (2018). Between Active Seekers and Non-Users: Segments of Science-related Media Usage in Switzerland and Germany. *Environmental Communication*, *28*(4), 1–18. https://doi.org/10.1080/17524032.2018.1463924

Metag, J., & Schäfer, M. S. (2018). Audience Segments in Environmental and Science Communication: Recent Findings and Future Perspectives. *Environmental Communication*, *12*(8), 995–1004. https://doi.org/10.1080/17524032.2018.1521542

Metag, J., Schäfer, M. S., Füchslin, T., Barsuhn, T., & Kleinen-von Königslöw, K. (2016). Perceptions of Climate Change Imagery: Evoked Salience and Self-Efficacy in Germany, Switzerland, and Austria. *Science Communication*, *38*(2), 197–227. https://doi.org/10.1177/1075547016635181

Metzger, M. J., Flanagin, A. J., & Medders, R. B. (2010). Social and Heuristic Approaches to Credibility Evaluation Online. *Journal of Communication*, *60*(3), 413–439. https://doi.org/10.1111/j.1460-2466.2010.01488.x

Miller, J. D. (1983). Scientific Literacy: A Conceptual and Empirical Review. *Daedalus*, *112*(2), 29–48. Retrieved from http://www.jstor.org/stable/20024852

Miller, J. D. (1986). Reaching the Attentive and Interested Public for Science. In S. M. Friedman, S. Dunwoody, & C. Rogers (Eds.), *Scientists and Journalists: Reporting Science as News* (pp. 55–69). New York, London: Free Press.

Miller, S. (2001). Public understanding of science at the crossroads. *Public Understanding of Science*, *10*(1), 115–120. Retrieved from https://doi.org/10.3109%2Fa036859

Morley, D. (2006). Unanswered Questions in Audience Research. *The Communication Review*, *9*(2), 101–121. https://doi.org/10.1080/10714420600663286

Morrison, M. [M.], Duncan, R., Sherley, C., & Parton, K. [K.] (2013). A comparison between attitudes to climate change in Australia and the United States. *Australasian Journal of Environmental Management*, *20*(2), 87–100. https://doi.org/10.1080/14486563.2012.762946

Morrison, M. [Mark], Parton, K. [Kevin], & Hine, D. W. (2018). Increasing belief but issue fatigue: Changes in Australian Household Climate Change Segments between 2011 and 2016. *PloS One*, *13*(6), e0197988. https://doi.org/10.1371/journal.pone.0197988

Moy, C. L., Locke, J. R., Coppola, B. P., & McNeil, A. J. (2010). Improving Science Education and Understanding through Editing Wikipedia. *Journal of Chemical Education*, *87*(11), 1159–1162. https://doi.org/10.1021/ed100367v

Napoli, P. M. (2012). Audience Evolution and the Future of Audience Research. *International Journal on Media Management*, *14*(2), 79–97. https://doi.org/10.1080/14241277.2012.675753

National Science Board (2018). Science & Engineering Indicators 2018: Broad-based, objective information on the U.S. and international S&E enterprise. Retrieved from https://www.nsf.gov/statistics/2018/nsb20181/

Neidhardt, F. (1993). The public as a communication system. *Public Understanding of Science*, *2*(4), 339–350. https://doi.org/10.1088/0963-6625/2/4/004

Nightingale, V. (2011). Introduction. In V. Nightingale (Ed.), *The Handbook of Media Audiences* (pp. 1–15). Wiley.

Nisbet, M. (2014). Models for Sustainable Infrastructure. In Elizabeth Stallman Brown, Laurence Yeung, and Keegan Sawyer, Rapporteurs, Roundtable on Public Interfaces of the Life Sciences, Board on Life Sciences, . . . National Research Council (Eds.), *Sustainable Infrastructures for Life Science Communication: Workshop Summary* (pp. 21–30). Washington (DC).

Nisbet, M., & Markowitz, E. M. (2014). Understanding public opinion in debates over biomedical research: Looking beyond political partisanship to focus on beliefs about science and society. *PloS One*, *9*(2), e88473. https://doi.org/10.1371/journal.pone.0088473

Nisbet, M. C., & Scheufele, D. A. (2009). What's next for science communication? Promising directions and lingering distractions. *American Journal of Botany*, *96*(10), 1767–1778. https://doi.org/10.3732/ajb.0900041

Noar, S. M., Benac, C. N., & Harris, M. S. (2007). Does tailoring matter?: Meta-analytic review of tailored print health behavior change interventions. *Psychological Bulletin*, *133*(4), 673–693. https://doi.org/10.1037/0033-2909.133.4.673

O'Neill, B. (2011). Media Effects in Context. In V. Nightingale (Ed.), *The Handbook of Media Audiences* (pp. 320–339). Wiley.

O'Neill, S. J., Boykoff, M., Niemeyer, S., & Day, S. A. (2013). On the use of imagery for climate change engagement. *Global Environmental Change*, *23*(2), 413–421. https://doi.org/10.1016/j.gloenvcha.2012.11.006

Office of Science and Technology, & the Wellcome Trust (2001). Science and the public: A review of science communication and public attitudes toward science in Britain. *Public Understanding of Science*, *10*(3), 315–330. Retrieved from https://doi.org/10.3109%2Fa036873

Okamura, K. (2016). Dynamic development of public attitudes towards science policymaking. *Public Understanding of Science (Bristol, England)*, *25*(4), 465–479. https://doi.org/10.1177/0963662515605420

Pew Research Center (August 2019). *Trust and Mistrust in Americans' Views of Scientific Experts*. Retrieved from https://www.pewresearch.org/science/2019/08/02/trust-and-mistrust-in-americans-views-of-scientific-experts/

Pullman, A., Chen, M. Y., Zou, D., Hives, B. A., & Liu, Y. (2018). Researching multiple publics through latent profile analysis: Similarities and differences in science and technology attitudes in China, Japan, South Korea and the United States. *Public Understanding of Science (Bristol, England)*, 963662518791902. https://doi.org/10.1177/0963662518791902

Rauchfleisch, A., & Schäfer, M. S. (2018). Structure and development of science communication research: co-citation analysis of a developing field. *Journal of Science Communication*, *17*(03). https://doi.org/10.22323/2.17030207

Raupp, J. (2017). Strategische Wissenschaftskommunikation. In H. Bonfadelli, B. Fähnrich, C. Lüthje, J. Milde, M. Rhomberg, & M. S. Schäfer (Eds.), *Forschungsfeld Wissenschaftskommunikation* (pp. 143–163). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-12898-2_8

Redlawsk, D. P. (2002). Hot Cognition or Cool Consideration? Testing the Effects of Motivated Reasoning on Political Decision Making. *The Journal of Politics*, *64*(4), 1021–1044. https://doi.org/10.1111/1468-2508.00161

Rimal, R. N., & Real, K. (2003). Perceived Risk and Efficacy Beliefs as Motivators of Change. *Human Communication Research*, *29*(3), 370–399. https://doi.org/10.1111/j.1468-2958.2003.tb00844.x

Rodgers, S., Chen, Q., Duffy, M., & Fleming, K. (2007). Media usage as health segmentation variables. *Journal of Health Communication*, *12*(2), 105–119. https://doi.org/10.1080/10810730601150064

Schäfer, M. S. (2011). Sources, Characteristics and Effects of Mass Media Communication on Science: A Review of the Literature, Current Trends and Areas for Future Research. *Sociology Compass*, *5*(6), 399–412. https://doi.org/10.1111/j.1751-9020.2011.00373.x

Schäfer, M. S. (2017). How Changing Media Structures Are Affecting Science News Coverage. In K. H. Jamieson, D. M. Kahan, D. A. Scheufele, & M. S. Schäfer (Eds.), *The Oxford Handbook of The Science of Science Communication.* Oxford University Press.

Schäfer, M. S., Füchslin, T., Metag, J., Kristiansen, S., & Rauchfleisch, A. (2018). The different audiences of science communication: A segmentation analysis of the Swiss population's perceptions of science and their information and media use patterns. *Public Understanding of Science (Bristol, England)*, *27*(7), 836–856. https://doi.org/10.1177/0963662517752886

Schäfer, M. S., Kristiansen, S., & Bonfadelli, H. (2015). Wissenschaftskommunikation im Wandel: Relevanz, Entwicklung und Herausforderungen des Forschungsfeldes. In M. S. Schäfer, S. Kristiansen, & H. Bonfadelli (Eds.), *Wissenschaftskommunikation im Wandel* (pp. 10–42). Köln: Herbert von Halem.

Schäfer, M. S., Metag, J., Feustle, J., & Herzog, L. (2018). Selling science 2.0: What scientific projects receive crowdfunding online? *Public Understanding of Science (Bristol, England)*, *27*(5), 496–514. https://doi.org/10.1177/0963662516668771

Scheufele, D. A. (2011). Modern citizenship or policy dead end? Evaluating the need for public participation in science policy making, and why public meetings may not be the answer. *Paper #R-34, Joan Shorenstein Center on the Press, Politics and Public Policy Research Paper Series*.

Scheufele, D. A. (2013). Communicating science in social settings. *Proceedings of the National Academy of Sciences of the United States of America*, *110 Suppl 3*, 14040–14047. https://doi.org/10.1073/pnas.1213275110

Scheufele, D. A. (2014). Science communication as political communication. *Proceedings of the National Academy of Sciences of the United States of America*, *111 Suppl 4*, 13585–13592. https://doi.org/10.1073/pnas.1317516111

Scheufele, D. A. (2018). Beyond the Choir?: The Need to Understand Multiple Publics for Science. *Environmental Communication*, *12*(8), 1123–1126. https://doi.org/10.1080/17524032.2018.1521543

Scheufele, D. A., & Krause, N. M. (2019). Science audiences, misinformation, and fake news. *Proceedings of the National Academy of Sciences of the United States of America.* Advance online publication. https://doi.org/10.1073/pnas.1805871115

Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2007). The constructive, destructive, and reconstructive power of social norms. *Psychological Science*, *18*(5), 429–434. https://doi.org/10.1111/j.1467-9280.2007.01917.x

Stilgoe, J. (2007). The (co-)production of public uncertainty: Uk scientific advice on mobile phone health risks. *Public Understanding of Science (Bristol, England)*, *16*(1), 45–61. https://doi.org/10.1177/0963662506059262

Suhay, E., Druckman, J. N., Kraft, P. W., Lodge, M., & Taber, C. S. (2015). Why People "Don't Trust the Evidence". *The ANNALS of the American Academy of Political and Social Science*, *658*(1), 121–133. https://doi.org/10.1177/0002716214554758

Tönnies, F. (1887). *Gemeinschaft und Gesellschaft: Abhandlung des Communismus und des Socialismus als empirischer Culturformen* (1st ed.). Leipzig: Fues.

Vogler, D., & Post, S. (2019). Reputation von Hochschulen. In B. Fähnrich, J. Metag, S. Post, & M. S. Schäfer (Eds.), *Forschungsfeld Hochschulkommunikation* (pp. 319–340). Wiesbaden: Springer Fachmedien Wiesbaden.

Walker, S., Mercea, D., & Bastos, M. (2019). The disinformation landscape and the lockdown of social platforms. *Information, Communication & Society*, *22*(11), 1531–1543. https://doi.org/10.1080/1369118X.2019.1648536

Welbourne, D. J., & Grant, W. J. (2016). Science communication on YouTube: Factors that affect channel and video popularity. *Public Understanding of Science (Bristol, England)*, *25*(6), 706–718. https://doi.org/10.1177/0963662515572068

Welsh, I., & Wynne, B. [Brian] (2013). Science, Scientism and Imaginaries of Publics in the UK: Passive Objects, Incipient Threats. *Science as Culture*, *22*(4), 540–566. https://doi.org/10.1080/14636778.2013.764072

Wissenschaft im Dialog (2018). Wissenschaftsbarometer 2018. Retrieved from https://www.wissenschaft-im-dialog.de/projekte/wissenschaftsbarometer/wissenschaftsbarometer-2018/

Wynne, B. [B.] (2007). Public Participation in Science and Technology: Performing and Obscuring a Political-Conceptual Category Mistake. *East Asian Science, Technology and Society*, *1*(1), 99–110. https://doi.org/10.1215/s12280-007-9004-7

Yeo, S. K., Xenos, M. A., Brossard, D., & Scheufele, D. A. (2015). Selecting Our Own Science. *The ANNALS of the American Academy of Political and Social Science*, *658*(1), 172–191. https://doi.org/10.1177/0002716214557782

Young, N., & Matthews, R. (2007). Experts' understanding of the public: knowledge control in a risk controversy. *Public Understanding of Science*, *16*(2), 123–144. https://doi.org/10.1177/0963662507060586

7 Publications

7.1 Schäfer, M. S., Füchslin, T., Metag, J., Kristiansen, S., & Rauchfleisch, A. (2018). The different audiences of science communication: A segmentation analysis of the Swiss population's perceptions of science and their information and media use patterns. Public Understanding of Science (Bristol, England), 27(7), 836–856. https://doi.org/10.1177/0963662517752886

7.2 Metag, J., Maier, M., Füchslin, T., Bromme, L., & Schäfer, M. S. (2018). Between Active Seekers and Non-Users: Segments of Science-related Media Usage in Switzerland and Germany. Environmental Communication, 28(4), 1–18. https://doi.org/10.1080/17524032.2018.1463924

7.3 Füchslin, T., Schäfer, M. S., & Metag, J. (2019). Who wants to be a citizen scientist? Identifying the potential of citizen science and target segments in Switzerland. Public Understanding of Science (Bristol, England), 28(6), 652-668. https://doi.org/10.1177/0963662519852020

7.4 Metag, J., Füchslin, T., & Schäfer, M. S. (2015). Global warming's five Germanys: A typology of Germans' views on climate change and patterns of media use and information. Public Understanding of Science (Bristol, England), 26(4), 434–451. https://doi.org/10.1177/0963662515592558

7.5 Füchslin, T. (2019). Science communication scholars use more and more segmentation analyses: Can we take them to the next level? *Public Understanding of Science (Bristol, England)*, *28*(7), 854-864. https://doi.org/10.1177/0963662519850086

7.6 Füchslin, T., Schäfer, M. S., & Metag, J. (2018). A Short Survey Instrument to Segment Populations According to Their Attitudes Toward Science. Scale Development, Optimization and Assessment. Environmental Communication, 12(8), 1095–1108. https://doi.org/10.1080/17524032.2018.1461673

7.7 Hargittai, E., Füchslin, T., & Schäfer, M. S. (2018). How Do Young Adults Engage With Science and Research on Social Media? Some Preliminary Findings and an Agenda for Future Research. Social Media + Society, 4(3), 205630511879772. https://doi.org/10.1177/2056305118797720

7.8 Kovic, M., & Füchslin, T. (2018). Probability and conspiratorial thinking. Applied Cognitive Psychology, 32(3), 390–400. https://doi.org/10.1002/acp.3408

7.9 Metag, J., Schäfer, M. S., Füchslin, T., Barsuhn, T., & Kleinen-von Königslöw, K. (2016). Perceptions of Climate Change Imagery: Evoked Salience and Self-Efficacy in Germany, Switzerland, and Austria. Science Communication, 38(2), 197–227. https://doi.org/10.1177/1075547016635181

7.1 Schäfer, Füchslin et al. (2018)

The different audiences of science communication: A segmentation analysis of the Swiss population's perceptions of science and their information and media use patterns.

Schäfer, M. S., Füchslin, T., Metag, J., Kristiansen, S., & Rauchfleisch, A.

This article was originally published in:

Schäfer, M. S., Füchslin, T., Metag, J., Kristiansen, S., & Rauchfleisch, A. (2018). The different audiences of science communication: A segmentation analysis of the Swiss population's perceptions of science and their information and media use patterns. *Public Understanding of Science (Bristol, England)*, *27*(7), 836–856. https://doi.org/10.1177/0963662517752886

Article

P | U | S

Public Understanding of Science
2018, Vol. 27(7) 836–856

DOI: 10.1177/0963662517752886
journals.sagepub.com/home/pus
SAGE

The different audiences of science communication: A segmentation analysis of the Swiss population's perceptions of science and their information and media use patterns

Mike S. Schäfer and Tobias Füchslin
University of Zurich, Switzerland

Julia Metag
Université de Fribourg, Switzerland

Silje Kristiansen
Northeastern University, USA

Adrian Rauchfleisch
University of Zurich, Switzerland

Abstract
Few studies have assessed whether populations can be divided into segments with different perceptions of science. We provide such an analysis and assess whether these segments exhibit specific patterns of media and information use. Based on representative survey data from Switzerland, we use latent class analysis to reconstruct four segments: the "Sciencephiles," with strong interest for science, extensive knowledge, and a pronounced belief in its potential, who use a variety of sources intensively; the "Critically Interested," also with strong interest and support for science but with less trust in it, who use similar sources but are more cautious toward them; the "Passive Supporters" with moderate levels of interest, trust, and knowledge and tempered perceptions of science, who use fewer sources; and the "Disengaged," who are not interested in science, do not know much about it, harbor critical views toward it, and encounter it—if at all—mostly through television.

Keywords
science attitudes and perceptions, science communication, survey, Switzerland

Corresponding author:
Mike S. Schäfer, University of Zurich, Andreasstrasse 15, Zurich CH-8050, Switzerland.
Email: m.schaefer@ipmz.uzh.ch

1. Introduction

Many scholars have scrutinized public perceptions of science in recent decades (for an overview, see Besley, 2013). Largely based on survey data, this research has shown that different sociodemographic groups differ in their knowledge about, support for, or trust in science (e.g. Office of Science and Technology (OST) and Wellcome Trust, 2000).

In light of such differences, it is likely that larger segments of the population can be reconstructed which differ in their perceptions of science. Yet only few studies have investigated such science-related segmentation (Guenther and Weingart, 2017; Kawamoto et al., 2013; Nisbet and Markowitz, 2014; OST, 2005; OST and Wellcome Trust, 2000). Therefore, we provide a segmentation analysis of the Swiss population, asking, first, *what segments of the population can be reconstructed which differ in their perceptions of science*? (RQ1).

In addition, the analysis of such segments' patterns of media and information use seems helpful. For many people, media are important sources of information about science (e.g. National Science Board, 2014), albeit they seemingly turn to them with different intentions and in different ways (e.g. Kahlor and Rosenthal, 2009). Information about segment-specific patterns of information use could therefore be helpful for devising communication strategies surrounding science. So far, however, few segmentation analyses on science included communicative patterns and those that did only considered general media use without describing it in detail. Therefore, our second research question asks, *how people belonging to the reconstructed segments differ in their patterns of science-related information and media use* (RQ2).

2. Conducting segmentation analyses in science communication

Perceptions of science and science communication

Research on the relationship between science and the public has intensified since the 1980s, with survey studies being of particular relevance. Early on, they were driven by the "deficit model" (e.g. Bucchi, 2008; Schäfer, 2009) of science communication. Large-scale surveys were established in the United Kingdom, the United States, and Europe to assess the public's knowledge—its "scientific literacy" (Miller, 1983)—and its perceptions of science (e.g. Eurobarometer, 2001; OST, 2005; OST and Wellcome Trust, 2000). Even when, later on, the deficit model made way for more dialogical models, survey research remained important and even expanded in many countries (cf. Besley, 2013).

This research has repeatedly shown that subgroups of the population differ in their perceptions of science. Differences in general attitudes toward science were found, for example, between people from urban and rural areas or with different educational levels in Japan (Kawamoto et al., 2013). Research also showed that perceptions of specific research fields, like animal experimentation (Von Roten, 2013), nuclear energy (Kristiansen et al., 2016), or nanotechnology (Lee et al., 2005), vary by sex, age, education, or religiosity in countries like the United States or Switzerland. Similarly, knowledge about science—both in general (e.g. Nisbet et al., 2002) and about specific fields (Kristiansen et al., 2016)—was shown to differ between sociodemographic groups.

The variation in these perceptions "represents a significant challenge for scientists, policy makers, and others tasked with effective communication[, as c]ertain types of messages may be enthusiastically embraced by some members of the general public, but elicit indifference or outrage from others" (Hine et al., 2014: 441). However, the question remains largely unanswered: what larger patterns can be found behind these individual-level differences. Few researchers have examined which segments of the population can be reconstructed that differ in their perceptions of science.

Identifying such segments and their profiles, however, would provide "policymakers, researchers, and communication practitioners with comprehensive and detailed knowledge of the target population and its subgroups" (Detenber et al., 2016). It would give them "an important strategic planning asset […] for making decisions about how to best allocate limited communication resources" (Hine et al., 2014: 442).

While research has shown segmentations among the public for issues such as climate change (for an overview, see Hine et al., 2014), energy (Sütterlin et al., 2011), or health (e.g. Maibach et al., 2006) repeatedly and in different countries, segmentations with regard to science have rarely been analyzed. The few exceptions from Japan, South Africa, the United Kingdom, and the United States differ in their approaches: while Kawamoto et al. (2013) segment the Japanese population according to a broad understanding of scientific literacy as well of respondents' interests in non-scientific topics, surveys in the United States and the United Kingdom focus on science-related perceptions (OST, 2005; OST and Wellcome Trust, 2000; Research Councils, 2008), and a South African study uses sociodemographic characteristics as the basis for segmentation (Guenther and Weingart, 2017). Accordingly, their findings are difficult to compare.

Segmentation analyses are also missing with regard to patterns of science-related information and media use. While the science of science communication has become an important field with a substantial and rising number of studies (Schäfer, 2012), it mirrors research on public perceptions of science with regard to the questions posed here: many studies have shown that uses and effects of science communication differ considerably between, for example, age groups, gender, and education levels. For example, science magazines or science TV shows are used to different degrees by different age groups or by people with different education levels in the United States (Nisbet et al., 2002), and science-specific information and media use patterns differ strongly between urban and rural areas in Latin America (Hurtado and Cerezo, 2012). Similar differences have been documented for the attendance of science events and museums and for personal conversations (e.g. Research Councils, 2008: 12ff.). But, again, whether and how these differences can be organized along different population segments has not been analyzed often. Only few segmentation analyses have included communicative patterns (e.g. Leiserowitz et al., 2010; Metag et al., 2017), and even fewer focused on science communication (Guenther and Weingart, 2017; Kawamoto et al., 2013; OST, 2005; OST and Wellcome Trust, 2000; Research Councils, 2008). But those found differences between population segments. They show, for example, that British "technophiles" use legacy media extensively to get information about science, while the "not for me" segment rarely encounters scientific content (OST and Wellcome Trust, 2000: 45, 62). Yet, these studies only consider a limited number of media and information variables, often restricting themselves to general media use with generic categories like "the internet" (e.g. Guenther and Weingart, 2017; Research Councils, 2008) and omitting respondents' evaluation of sources (e.g. Eveland, 2001) or their motivations for tending to them (cf. Kahlor and Rosenthal, 2009).

Types of segmentation analyses

Generally, segmentation analyses aim to "divide the general public into relatively homogeneous, mutually exclusive subgroupings" (Hine et al., 2014: 442). In communication science or (social) marketing, analyses of audience segmentation are often undertaken so that, in a second step, "appropriate message design and communication strategies can be developed to influence attitudes and behaviors" (Slater, 1996: 272).[1]

Segmentation analyses have employed different research designs ranging from qualitative interview and focus group studies to standardized surveys and, more recently, analyses of social media. Among them, large-scale quantitative survey analyses have been described as particularly advantageous if the identified segments are to be representative for a larger population, with national probability samples being the "gold standard" (Hine et al., 2014: 452).

Three basic logics have been applied in order to select variables for segmentation: older studies often used *sociodemographic variables* for segmentation (Dibb and Simkin, 2009). Studies "discriminate[d] between audience or market groups on the basis of easily accessed variables, such as demographics (education, race, income, gender)" (Slater, 1996: 269) which were later "cross-tabbed with media use and some key psychosocial variables such as involvement and behavior" (268f.). The usefulness of this approach, however, is limited to the few cases where sociodemographic characteristics are strong predictors of the attitudinal or behavioral variables of interest (Yankelovich and Meer, 2006: 123f.).

Recent segmentation analyses have mostly used one of two approaches (for an overview, see Lotenberg et al., 2011): on one hand, they used respondents' attitudes toward a topic or object, that is, "psychographic" variables (Wind, 1978: 319f.), for segmentation. Such studies are available, for example, for respondents' attitudes toward health (Noar et al., 2007), energy (Sütterlin et al., 2011), or climate change (Hine et al., 2014). On other hand, scholars from fields like marketing have criticized that while segmentations based on psychographic variables "may capture some truth about real people's lifestyles, attitudes, self-images and aspirations," they are criticized for being weak at predicting behavior (Yankelovich and Meer, 2006: 124). As a result, they have argued for segmentation analyses centered around behavioral data (Yankelovich and Meer, 2006: 125f.) or channels of communication (cf. Lotenberg et al., 2011).

This criticism, however, sells the advantages of "psychographic" segmentations short. These have shown, for example, that segments are stable over time (e.g. Leiserowitz et al., 2013), that they correlate with people's general values (e.g. Roser-Renouf et al., 2016), and that they can be better predictors of science-related policy support than political ideology and sociodemographic variables (Maibach et al., 2011). Moreover, they have demonstrated that people in different segments also differ in their media diets (Metag et al., 2017) and that segmentation can improve communication efforts by facilitating targeted messages (Noar et al., 2007). Therefore, and because almost no segmentation analyses about the attitudes toward and perceptions of science exist so far, we will segment "psychographically." In a second step, we will then take communication and media-related variables into account.

The degree to which segmentation analyses are theoretically guided differs (Dibb and Simkin, 2009). There are studies which are based on coherent theoretical frameworks, but they are uncommon due to the lack of specific theoretical models for science communication (Hine et al., 2014: 447) and their sometimes limited use for planning communication campaigns (Slater, 1996: 273). In contrast, many segmentation analyses employ an "atheoretical 'whatever works'" (Hine et al., 2014: 448) approach without specifying a conceptual basis for variable selection (cf. Dibb and Simkin, 2009). The middle ground are studies which provide rationales for selecting individual variables based on earlier analyses and different concepts in science communication (cf. Hine et al., 2014; Metag et al., 2017). These studies make up the majority of segmentation analyses in science-related fields and offer the advantage that different theoretical concepts can be taken into account. We employ this approach as well.

Relevant factors for a segmentation analysis of science communication

Our analysis derives the core dimensions it uses for segmentation from the large field of science-related survey research in general (Besley, 2013) and the small number of previous segmentation analyses (e.g. Kawamoto et al., 2013; OST, 2005).

The first dimension concerns *general attitudes toward science*. Social psychologists (Ajzen, 1989) have proposed a broad understanding of attitudes covering cognitive, affective, and conative aspects:

- The cognitive *aspect* of attitudes refers to information about an attitude object or perceptions of it (Ajzen, 1989: 242f.). With regard to science, it has most often been used as knowledge about science or "scientific literacy" (Kawamoto et al., 2013; Miller, 1983), which referred to factual knowledge about scientific findings early on and has since been extended to also include knowledge about scientific procedures. A second cognitive aspect is people's interest in science (Kawamoto et al., 2013: 680).
- The *affective aspect* of attitudes "has to do with feelings towards the attitude object" (Ajzen, 1989: 243). Due to its inherently non-rational, affective nature (Engdahl and Lidskog, 2014; Schäfer, 2016), trust in science and its protagonists has been used as such an affective attitude toward science (Lee et al., 2005).
- The *conative aspect* refers to "behavioral intentions … or actions with respect to the attitude object" (Ajzen, 1989: 244). With regard to science, this dimension has often been operationalized as people's search for information about scientific issues (cf. Bauer, 2016; Eurobarometer, 2005). With the advent of citizen science, a second conative facet has been included in some surveys: people's desire to partake in research projects themselves (Wissenschaft Im Dialog, 2015).

The second dimension refers to people's *reservations and beliefs* with regard to the "promise of science" (Bauer, 2016). To capture these hopes and concerns about science and its potential to solve societal problems, survey questions already exist that were developed and tested in several countries (e.g. Eurobarometer, 2005; National Science Board, 2014; Prpic, 2011).

Third, people's subjective *norms with regard to science and science communication* have been described as relevant for their perceptions of science and have been shown to have behavioral consequences (Ajzen, 2001; Bamberg and Möser, 2007):

- The first are normative *preferences regarding the relation of science and society*. People have different assessments regarding the necessity of science in general (Eurobarometer, 2010), its need for public funding (Wissenschaft Im Dialog, 2015), its role in political decision-making (Bauer, 2016), the role of the public in defining science's agenda (Wissenschaft Im Dialog, 2015), or the duty of scientists to inform the public about their work (Mejlgaard and Stares, 2010).
- The second normative facet concerns *people's own norms* (Ajzen, 2001, 2002) with regard to being informed about science. Descriptive norms refer to the extent to which people believe one should be informed about science. Injunctive norms describe to what extent people think that they are expected to be informed about science by their peers (Kahlor et al., 2006).

We will use these dimensions to segment the Swiss population according to their perceptions of science. Subsequently, we analyze whether these segments differ in their *information and media use*. As research has shown that people use different sources for information about science (for an overview, see Metag, 2017), we will take different sources and individual assessments of these into account. This will provide more detailed information about information and media use than surveys like the Eurobarometer (2010) or the Science and Engineering Indicators (National Science Board, 2014):

- First, *news* media like TV, radio, or printed publications such as science magazines have been shown to be important sources of information about science for many people (e.g. Nisbet et al., 2002). In addition, audience segments that were described for issues like climate change (Leiserowitz et al., 2010; Metag et al., 2017) have been shown to differ in their news media use.
- Second, *online sources and social media* have gained importance with regard to scientific issues (Brossard, 2013; Brossard and Scheufele, 2013; Schäfer, 2017). This includes websites as well as social media like Wikipedia, Facebook, video portals, blogs, and online forums.
- Third, *sources of information beyond news and online media* have to be considered, as research has shown that some people inform themselves about scientific issues in non-fiction books, museums and science centers, zoos and aquariums, talks, or science-related events (e.g. BBVA Foundation, 2011; Eurobarometer, 2010; OST and Wellcome Trust, 2000).
- Apart from the frequency of contact, fourth, research has demonstrated that the *ways in which people turn to, perceive, and evaluate science-related information* influence the outcome of science communication and attitudes toward science. Building on this research and on concepts from communication science such as information seeking or uses and gratifications approaches, we also analyze people's evaluation of media content, their attentiveness when consulting those sources (Eveland, 2001; Eveland et al., 2009), and their motivations and expected gratifications for using them (Kahlor and Rosenthal, 2009).

In addition, *sociodemographic characteristics* have been shown to be associated with perceptions of science and information behaviors (Besley, 2013; Nisbet et al., 2002).

3. Data and methods

Data

We use data from the representative "Science Barometer Switzerland" (Wissenschaftsbarometer Schweiz) survey from 2016. They assess the Swiss population's attitudes toward beliefs in and knowledge about science and research. Based on public telephone listings (90% landlines, 10% mobile), households were randomly selected, household members were chosen according to sex and age quotas and were interviewed using computer-assisted telephone interviews (CATI). A total of 1051 respondents participated (651, 200, 200 from the German-, French-, and Italian-speaking parts of the country, respectively). The final sample was weighted regarding cantons,[2] size of living area, gender, age, education, occupation, and household size.

Measurements

Attitudes toward science were measured regarding cognitive, affective, and conative aspects (see Table 1 for detailed information):

- To assess the *cognitive aspect*, we measured respondents' knowledge about science. Often, quiz questions were used in surveys to assess knowledge (Kawamoto et al., 2013; Miller, 1983), but they have been criticized extensively (e.g. Pardo and Calvo, 2002, 2004). Taking up the major criticisms, we used the traditional quiz format in adapted form. First, we included questions about arts and humanities, about textbook and applied scientific

Table 1. Items used in our study.

Dimension	Items	*N*	*M*	*SD*
Attitudes toward science and research				
Cognitive	Scientific literacy (index: 0–2; no/incorrect answer = 0 pt, correct "likely" answer = 1 pt, correct "definitely" answer = 2 pts)	1051	1.23	0.36
	How interested are you in science and research? (1 = "not at all" … 5 = "very interested")	1050	3.45	1.11
Affective	Science and research play an important role in my life (1 = "do not agree at all" … 5 = "agree strongly")	1044	3.14	1.19
	How high is your trust in science in general? (1 = "very low" … 5 = "very high")	1042	3.58	0.74
Conative	I specifically search for information about science and research (1 = "do not agree at all" … 5 = "agree strongly")	1048	3.13	1.35
	I would like to partake in scientific research once (1 = "do not agree at all" … 5 = "agree strongly")	1043	2.86	1.39
"Reservations versus beliefs in the promise of science"	Science and technology can sort out any problem (1 = "do not agree at all" … 5 = "agree strongly")	1049	2.16	1.01
	Science and research make our lives better (1 = "do not agree at all" … 5 = "agree strongly")	1049	3.75	0.91
	Science makes our ways of life change too fast (1 = "do not agree at all" … 5 = "agree strongly")	1043	3.03	1.15
	The benefits of science are greater than any harmful effects it may have (1 = "do not agree at all" … 5 = "agree strongly")	1017	3.11	1.05
	Science should have no limits to what it is able to investigate (1 = "do not agree at all" … 5 = "agree strongly")	1043	2.60	1.26
	Science will eventually provide a full picture of how nature and the universe works (1 = "do not agree at all" … 5 = "agree strongly")	1041	2.87	1.26
	We rely too heavily on science (1 = "do not agree at all" … 5 = "agree strongly")	1042	3.03	1.02
Subjective norms				
Desirable relation between science and society	Scientific research is necessary even if there is no immediate application (1 = "do not agree at all" … 5 = "agree strongly")	1044	4.02	1.03
	Scientific research should be publicly funded (1 = "do not agree at all" … 5 = "agree strongly")	1039	4.04	0.99
	Scientists should inform the public about their work (1 = "do not agree at all" … 5 = "agree strongly")	1047	3.99	0.94
	Scientists should listen more to what regular people think (1 = "do not agree at all" … 5 = "agree strongly")	1039	3.29	1.23
	Political decisions should be based on scientific findings (1 = "do not agree at all" … 5 = "agree strongly")	1031	3.48	1.06
	People like me should be involved in decisions about the topics scientists research (1 = "do not agree at all" … 5 = "agree strongly")	1037	2.51	1.14
Informational norms	It is important to be informed about science and research (1 = "do not agree at all" … 5 = "agree strongly")	1048	3.90	0.98

(Continued)

Table 1. (Continued)

Dimension	Items	*N*	*M*	*SD*
Associations (3 per respondent) with "science and research"	If you think about science and research, what topics first come to your mind?	3153	NA	NA
Sociodemographics	Gender (% female)	1051	50.8	–
	Age (years)	1051	46.3	17.90
	Education (% tertiary education)	1046	43.3	–
	Proximity to science (index: 0–4)	1049	1.59	1.26
	Religiosity (1 = "not at all religious" … 5 = " very religious")	1047	2.72	1.25
	Political orientation (1 = "left" … 7 = "right")	998	3.64	1.28
Mass media contact with science and research	How often do you come in contact with science and research via … (always from 1 = "never" … 5 = "very often")			
	Swiss public television (SRF)	1045	2.86	1.20
	Other television	1034	2.65	1.23
	Swiss public radio (SRF Radio)	1040	2.36	1.29
	Other radio	1036	1.64	1.00
	Daily/weekly newspapers and magazines	1042	3.28	1.22
	Science magazines	1032	1.95	1.28
	Internet	1045	3.12	1.38
Online contact with science and research	How often do you come in contact with science and research via … (always from 1 = "never" … 5 = "very often")			
	Online outlets of newspapers and magazines	1042	2.23	1.33
	Online archives of television and radio channels	1039	1.90	1.14
	Institutional websites (scientific, government, organizations)	1041	2.31	1.28
	Facebook	1044	1.55	1.06
	Blogs or message boards	1042	1.54	0.90
	Wikipedia	1040	2.72	1.40
	YouTube or similar video platforms	1043	2.22	1.29
Others contact with science and research	How often do you do one of the following … (always from 1 = "never" … 5 = "very often")			
	Visit museums and exhibitions covering science and research	1049	2.47	1.08
	Visit zoos, aquariums, or botanical gardens	1050	2.71	1.13
	Attend events, talks, discussions concerning science, and research	1050	2.09	1.09
	Read non-fiction books on science and research	1051	2.51	1.28
	Watch movies related to science and research in the cinema	1049	2.32	1.18
	Talk about science and research with friends and acquaintances	1051	3.11	1.12
Patterns of information and media use	How attentive are you when media report on scientific topics? (1 = "not attentive at all" … 5 = "very attentive")	1050	3.12	0.98

Table 1. (Continued)

Dimension	Items	N	M	SD
Assessment of media coverage	Generally, do you think media coverage about science and research is … (always from 1 = "do not agree at all" … 5 = "agree strongly")			
	Trustworthy	1031	3.34	0.85
	Able to show how science is relevant in my life	1028	2.90	1.01
	Comprehensible	1025	3.38	0.93
	Extensive	1007	3.17	0.87
Motivations for tending to scientific content	How important are the following reasons for you to deal with science and research? (always from 1 = "not important at all" … 5 = "very important")			
	To inform myself for school/work	1044	3.47	1.27
	Because I'm curious	1051	3.86	1.08
	To better understand science and research	1047	3.62	1.05
	To be able to participate when others talk about science and research	1046	2.99	1.13
	To fact-check information	1047	3.29	1.09

M: arithmetic mean; *SD*: standard deviation.

knowledge (cf. Pew Research Center, 2013), and also about the process of science. Second, we moved from the established dichotomous "correct–false" answer format, which gives respondents a 50% random chance to answer correctly to a format allowing respondents to indicate the level of certainty in their answers (cf. BBVA Foundation, 2011: 19ff.).[3] Answers for the 11 items from the "Science Barometer Switzerland" were combined in an index: correct answers gave respondents one point for the "likely" and two points for the "definitely" version. Incorrect or "do not know" answers were assigned zero points. The index value is the arithmetical mean of points per question, ranging from 0 to 2. In addition to knowledge, we asked for respondents' *interest in science*, employing a question that was widely used in several surveys (e.g. BBVA Foundation, 2011; Eurobarometer, 2010; OST and Wellcome Trust, 2000).

- The *affective aspect* of attitudes was measured by asking respondents for their general trust in science (Lee et al., 2005) as well as for their assessment of whether science plays an important role in their lives.
- We assessed the *conative aspect* with two questions asking whether respondents search for information about science actively and whether they would like to be personally involved in a research project once (cf. Wissenschaft Im Dialog, 2015).

Respondents' *reservations and beliefs* with regard to science were assessed with sets of questions used in international surveys before. We used an adapted variant of the shortened version developed by Prpic (2011).

People's *norms with regard to science and science communication* were assessed, first, by combining questions from different surveys (Besley, 2013; Eurobarometer, 2010; Nisbet et al., 2002: 591) asking for respondents' preferences regarding the relation of science and society. Furthermore, people's own informational norms with regard to science were assessed (Kahlor et al., 2006).

To contextualize attitudes toward science, we *asked respondents what they associated with the survey's topic, that is, with "science and research."* The survey contained an open question asking for up to three associations. Most respondents provided at least one association. These were recoded into disciplines according to the OECD (2007) taxonomy and into general descriptions of science.

In addition, we analyzed respondents' *patterns of information and media use*. We asked through which mass media they get into contact with science (BBVA Foundation, 2011; Schäfer and Taddicken, 2015). Respondents who indicated to get into contact with science via Internet were asked detailed questions about online platforms and social media (cf. OST and Wellcome Trust, 2000; Pew Research Center, 2013). In addition, we included sources such as museums, zoos, aquariums, science-related events, or non-fiction books (e.g. BBVA Foundation, 2011; OST and Wellcome Trust, 2000).

We also asked for *qualitative information about media use*: respondents' assessments of media coverage's ability to explain science's relevance as well as their evaluation of the extent, comprehensibility, and trustworthiness of media reporting (mostly based on Macedo-Rouet et al., 2003; Tsfati et al., 2011), their attentiveness when encountering scientific topics in media (adapting a question from Fredin et al., 1996), and their motivations for tending to scientific content (adapting scales from Rössler, 2011: 4ff.).

Eventually, we included *sociodemographic characteristics* (age, sex, and education (Besley, 2013; Nisbet et al., 2002), *religiosity* (OST and Wellcome Trust, 2000), *political orientation* (cf. Nisbet et al., 2002), and an index of people's personal or professional *proximity to science* (BBVA Foundation, 2011). For this index, respondents were first asked whether they were scientists themselves. If not, they were asked whether they "personally knew a scientist," "have family members that study or studied at university level," and "come in contact with science through their work." Each affirmative answers resulted in one index point. Scientists were directly assigned four points, resulting in a sum index from 0 to 4.

Method

Segmentation analyses aim to split populations into homogeneous subgroups that differ with regard to relevant variables. Such analyses commonly use one of two approaches: some employ factor analysis first to reduce variable complexity and administer distance-based clustering methods such as hierarchical or k-means clustering afterward (Kawamoto et al., 2013; OST, 2005; OST and Wellcome Trust, 2000). Others cluster variables in their original forms directly, mostly using a model-based method such as latent class analysis (LCA; Maibach et al., 2011; Morrison et al., 2013).

The main advantage of the first approach is the reduction in the number of variables, which simplifies cluster interpretation. It also results in continuous variables and thus lends itself to distance-based clustering methods. The disadvantage, however, is a substantial loss of information. Factor analyses are likely to exclude unsuitable variables, while other variables will only be maintained with low factor loadings.

LCA, in turn, has several advantages: It can handle any variable level, large numbers of variables (McLachlan and Peel, 2004; Magidson and Vermunt, 2002b), and higher numbers of missing values (Maibach et al., 2006). Since cluster solutions are based on a statistical model, measures to compare model fit can be used and the predictive power of indicators is denoted (Linzer et al., 2011). On top, LCA has been shown to outperform distance-based measures such as k-means (Magidson and Vermunt, 2002a). Therefore, LCA has been described as the "preferred strategy for generating audience segments" (Hine et al., 2014). We apply it as well.

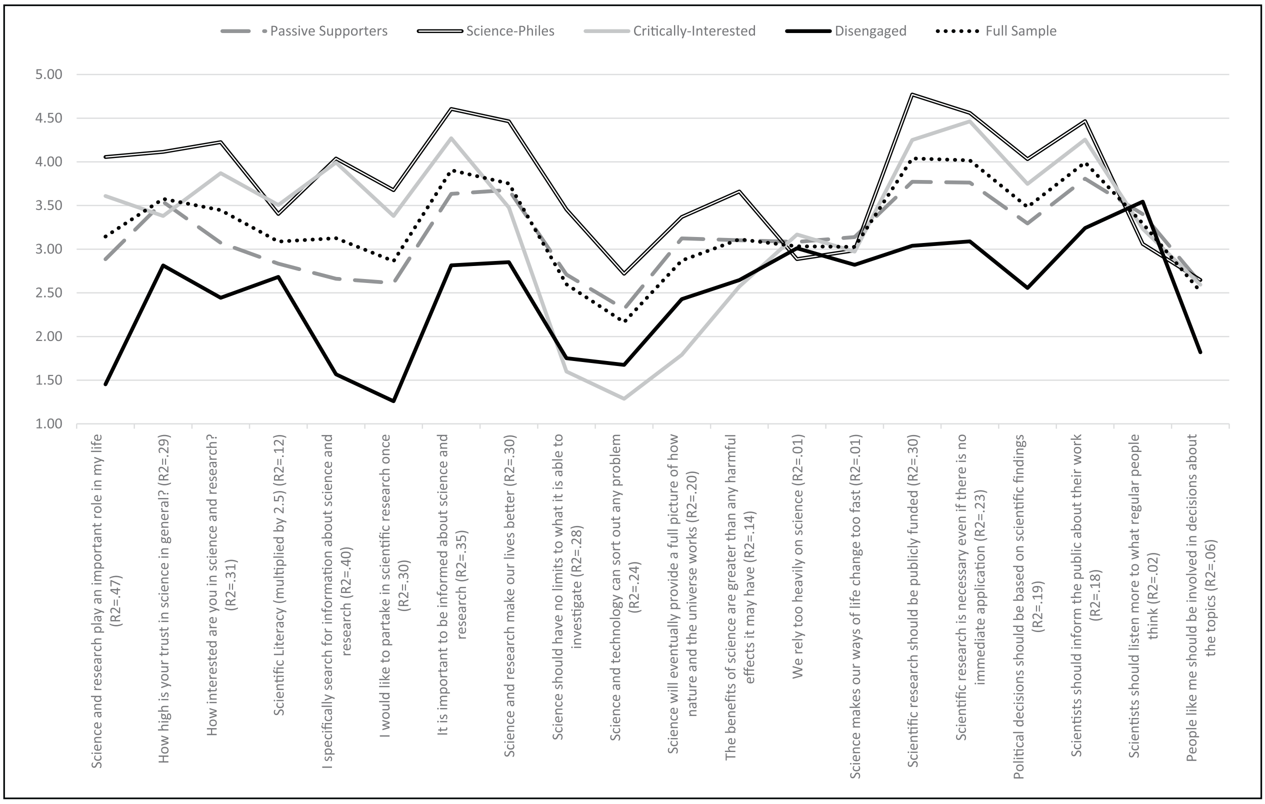


Figure 1. Segment means along the 20 cluster variables, including the variables' R^2 values.

Using the above-mentioned variables covering attitudes toward science, reservations, and beliefs and science-related informational norms, we determined optimal solutions from 2 up to 15 clusters using LatentGold 5.1 software (Vermunt and Magidson, 2016). A total of 5000 random sets of starting values were entered into the algorithm to ensure validity and robustness of each solution. Bayesian information criterion (BIC) values showed two- or three-cluster solutions to be unfavorable. All other solutions were on similar levels. The four-cluster solution offered the clearest interpretation.[4] It yielded 94.7% correctly assigned cases in discriminant analysis and conserved the full representative sample size (N=1051). We assessed segment means through modal attribution of cases, that is, each case was assigned to its most probable segment. For more than 99% of respondents, the likelihood of belonging to one segment exceeded 50%. Furthermore, the overall hit rate—defined as the sample mean of all respondents' posterior probabilities (cf. Gollwitzer, 2012)—reached 89%.

4. Results

The segmentation of the population: Four perspectives on science

The four population segments that were reconstructed have distinct perceptions of science. Figure 1 shows the means of the four segments along the 20 cluster variables as well as their R^2 values, indicating which variables are more differentiating between the segments than others:

1. The "*Sciencephiles*" (n=292) form the second largest segment representing 27.8% of the Swiss population. They mostly associate "science and research" with the natural sciences (which account for 22.5% of their associations), followed by medicine (20.7%),

engineering (13.2%), and, albeit less often, the social sciences (5.3%). The "Sciencephiles" know a lot about science and exhibit the highest means on almost all variables regarding attitudes and beliefs toward science and research: They feel that science is important in their lives, have a strong interest, and high trust in it. More than all other segments, they think it is important to be informed about science, actively seek information about it, and are the most interested in partaking in research projects. Also, they are highly supportive of science, think scientists should inform the public, and that scientific findings should influence political decisions. Regarding the promises of science, they are the most hopeful and least critical. They strongly believe science improves our lives and oppose research constraints. Although they do not think science can solve every problem, they are the most optimistic segment regarding this question.

2. The "*Critically Interested*" segment encompasses 17.2% ($n=181$) of all respondents. When they hear "science and research," they also mostly associate the natural sciences (22.6%) and medicine (20.7%), followed by engineering (12.0%) and—rather strongly compared to all other segments—the social sciences (6.9%). Their knowledge about and attitudes toward science are similar to the "Sciencephiles." The main difference is that they trust science considerably less and have stronger reservations regarding science's promises. While the "Critically Interested" think that science is important in our lives, they also strongly favor research constraints, think science cannot solve every problem, and that it will not provide a full picture of the world eventually. Despite these criticisms, the "Critically Interested" are only slightly less supportive of science than the "Sciencephiles." They do not question public funding or the necessity of basic research, think research findings should be incorporated in political decisions, and want to be informed about scientists' work.

3. The "*Passive Supporters*" ($n=437$, 41.5%) are the largest group. For them, "science and research" is mostly medicine (22.3%), followed by the natural sciences (17.9%) and engineering (9.5%). Social sciences (3.4%) or humanities (0.5%) only account for few associations in this segment. Their attitudes toward science are moderate: they are rather interested in science, trust it, and tend to think that it is important to be informed about it. But they do not often seek information about science, and their interest in "citizen science" is only moderate. Overall, their reservations and beliefs regarding science are not strongly pronounced. They think science improves our lives, might provide a full picture of the world, and is generally beneficial for society. But they do not believe that science should have no constraints or that it can solve every problem. The "Passive Supporters" support public funding and basic research, albeit less so than the "Critically Interested" and the "Sciencephiles." Like the previous segments, they think scientists should inform the public about their work.

4. The "*Disengaged*" ($n=141$; 13.4%) are the smallest segment. They have the highest proportion of respondents who do not provide a single association with "science and research." Those who did thought mostly of medicine (19.5%) and the natural sciences (11.7%), with engineering (4.8%), the social sciences (2.2%), and humanities (0.1%) remaining marginal. The "Disengaged" are also moderately in favor of basic research and public funding. But they perceive science more negatively than the other groups and oppose the "Sciencephiles'" views in many respects. They consider science not to be

important in their lives, almost never seek information about it, and are hardly interested in partaking in research. They have the lowest interest and trust in science and are not convinced that it is important to be informed about it. They also have the lowest level of scientific literacy. They favor some research constraints and think that humanity relies too heavily on science.

Media and information use patterns: The segmented audience of science communication

In addition to their different perceptions of science, people grouped in the four segments differ sociodemographically and in their information and media use (cf. Table 2):

1. A total of 61.6% of the "*Sciencephiles*" are male respondents—the highest proportion among the segments. They also show the highest level of education and proximity to science of all groups. While they are the oldest segment (47.6 years), age does not differ significantly between the groups.
   They use a broad range of sources to encounter scientific content—most often Internet, particularly on Wikipedia and institutional websites, whereas Facebook or blogs are their least likely sources. They also encounter science often in newspapers and magazines and, on a lower level, on TV. Among all groups, they read science magazines most often.
   In addition, they evaluate media reporting on science most positively in terms of trustworthiness, accuracy, comprehensibility, and ability to explain science's relevance. Overall, they are the most attentive when scientific topics come up in the media and also engage with science elsewhere: more than most other segments, they talk to friends and acquaintances about it, read science books, and go to scientific museums and exhibitions.
   Their motivations to engage with scientific content are high. No other group wants to participate in conversations about science and research as much. Their motives for doing so are intrinsic: the "Sciencephiles" are driven by personal curiosity and their willingness to better understand science and research.

2. The "*Critically Interested*" are, again, similar to the "Sciencephiles" in many ways. They are highly educated, have a close proximity to science, and have a liberal leaning political orientation. They are, however, significantly more religious than the "Sciencephiles."
   In addition, they mostly share the "Sciencephiles'" patterns of media and information use. They use the same set of mass media to similar degrees, tend to the same online and social media (with the exception of reading online newspapers and magazines less often) and use the same non-media sources to tend to scientific topics, such as talking to their peers or reading science books. Moreover, they do so for reasons very similar to those of the "Sciencephiles."
   The main differences between the "Sciencephiles" and the "Critically Interested" lie in their evaluations of science-related media content. Not only are the "Critically Interested" less attentive toward such content, but also they are more critical. For example, they do not think that the coverage is very extensive. Their evaluations of media coverage are closer to those of the "Passive Supporters."

Table 2. Additional description of segments.

	"Sciencephiles" (n = 292)	"Critically Interested" (n = 181)	"Passive Supporters" (n = 437)	Disengaged (n = 141)
Sociodemographics				
Gender (% female)	38.4[a,b]	48.8	55.8[a]	63.4[b]
Age (years)	47.6	46.3	45.9	45.1
Education (% tertiary education)	58.5[a,d]	58.8[b,e]	35.0[a,b,c]	17.3[c,d,e]
Proximity to science (index: 0–4)	2.20[a,d]	2.06[b,e]	1.28[a,b,c]	0.69[c,d,e]
Religiosity (1 = "not at all religious" … 5 = " very religious")	2.43[a,b]	2.81[b]	2.85[a]	2.76
Political orientation (1 = "left" … 7 = "right")	3.56	3.31[a,b]	3.79[a]	3.74[b]
Contact with science and research via mass media (1 = "never" … 5 = "very often")				
Swiss public television (SRF)	2.99	2.70	2.89	2.70
Other television	2.82[b]	2.64[c]	2.68[a]	2.19[a,b,c]
Swiss public radio (SRF radio)	2.36	2.32	2.43	2.21
Other radio	1.67	1.41[a]	1.69[a]	1.69
Daily/weekly newspapers and magazines	3.63[a,c]	3.39[d]	3.23[a,b]	2.54[b,c,d]
Science magazines	2.55[a,d]	2.19[b,e]	1.68[a,b,c]	1.21[c,d,e]
Internet	3.76[a,d]	3.52[b,e]	2.87[a,b,c]	2.04[c,d,e]
Contact with science and research via online media (1 = "never" … 5 = "very often")				
Online outlets of newspapers and magazines	2.78[a,c,d]	2.19[c,e]	2.08[a,b]	1.59[b,d,e]
Online archives of television and radio channels	2.24[a,b]	2.01[c]	1.76[a]	1.45[b,c]
Institutional websites (scientific, government, organizations)	3.00[a,d]	2.70[b,e]	1.95[a,b,c]	1.44[c,d,e]
Facebook	1.58	1.41	1.64	1.41
Blogs or message boards	1.73[b]	1.57[c]	1.50[a]	1.23[a,b,c]
Wikipedia	3.33[a,d]	3.04[b,e]	2.55[a,b,c]	1.59[c,d,e]
YouTube or similar video platforms	2.51[a,c]	2.44[d]	2.14[a,b]	1.59[b,c,d]
Other contact with science and research (1 = "never" … 5 = "very often")				
Visit museums and exhibitions covering science and research	2.81[a,d]	2.76[b,e]	2.35[a,b,c]	1.82[c,d,e]
Visit zoos, aquariums, or botanical gardens	2.73	2.71	2.73	2.60
Attend events, talks, discussions concerning science and research	2.50[a,d]	2.47[b,e]	1.90[a,b,c]	1.34[c,d,e]
Read non-fiction books on science and research	3.16[a,d]	3.10[b,e]	2.21[a,b,c]	1.31[c,d,e]
Watch movies related to science and research in the cinema	2.64[a,d]	2.53[b,e]	2.25[a,b,c]	1.61[c,d,e]
Talk about science and research with friends and acquaintances	3.65[a,d]	3.55[b,e]	2.91[a,b,c]	2.02[c,d,e]
Patterns of information and media use				
How attentive are you when media report on scientific topics? (1 = "not attentive at all" … 5 = "very attentive")	3.72[a,d,e]	3.35[b,d,f]	2.92[a,b,c]	2.17[c,e,f]
Assessment of media coverage (1 = "do not agree at all" … 5 = "agree strongly")				
Trustworthy	3.53[b,c]	3.28[b,d]	3.36[a]	2.94[a,c,d]

(Continued)

Table 2. (Continued)

	"Sciencephiles" (*n* = 292)	"Critically Interested" (*n* = 181)	"Passive Supporters" (*n* = 437)	Disengaged (*n* = 141)
Able to show how science is relevant in my life	3.38[a,c,d]	2.98[c,e]	2.77[a,b]	2.14[b,d,e]
Comprehensible	3.83[a,c,d]	3.45[c,e]	3.24[a,b]	2.78[b,d,e]
Extensive	3.29[c,d]	2.98[a,c]	3.27[a,b]	2.81[b,d]
Motivations for tending to scientific content (1 = "not important at all" … 5 = "very important")				
To inform myself for school or work	3.90[a,d]	3.80[b,e]	3.33[a,b,c]	2.60[c,d,e]
Because I am curious	4.47[a,d]	4.30[b,e]	3.65[a,b,c]	2.63[c,d,e]
To better understand science and research	4.23[a,d,e]	3.93[b,d,f]	3.42[a,b,c]	2.54[c,e,f]
To be able to participate when others talk about science and research	3.49[a,c,d]	3.10[c,e]	2.90[a,b]	2.10[b,d,e]
To fact-check information	3.70[a,d]	3.59[b,e]	3.13[a,b,c]	2.57[c,d,e]

Means in the same row that share superscripts differ at $p < .05$ in the post hoc test (Scheffé).

3. The "*Passive Supporters*" are on average 45.9 years old, 55.8% of them are female respondents, and their education levels are below the previous two segments.
   As a general pattern, they rank below the people grouped in the "Sciencephiles" and "Critically Interested" segments and above the "Disengaged." For example, their attentiveness to scientific content in the media is significantly higher than that of the "Disengaged" but significantly lower than that of the other two segments. Also, they are most likely to encounter science through daily or weekly newspapers and magazines and on the Internet, but each with the second lowest mean across clusters. Moreover, while they most often get in contact with science on Wikipedia, they only do so significantly more often than the "Disengaged" and significantly less than the other two segments. Their assessments of science reporting are mostly on par with the full sample means, that is, on a moderate level. If anything, they do not fully agree that the reporting is able to explain them science's relevance.
   The "Passive Supporters" do not use non-mediated sources very often. If they do, they are most likely to talk about science with friends and acquaintances or visit zoos, aquariums, or botanical gardens. Also, while they are curious about science and research, this number is significantly lower compared to the previous segments.

4. Among respondents in the "*Disengaged*" segment, the proportion of women is the highest (63.4%). The average age of this segment is 45.1 years. They have, by far, the lowest level of education and the largest personal and professional distance to science.
   Their low interest and critical perception of science translates into a low motivation to engage with science and research at all and into having the fewest contacts with science across almost all mass media and online sources. The only sources they use as often as others regarding science are public TV—the "Disengaged's" main source—public radio, and Facebook. Apart from only rarely consuming science-related content, this segment is also the most critical toward this content, evaluating the trustworthiness and comprehensibility of media reporting of science comparatively negatively and not thinking that the reporting makes science's relevance clear.

The "Disengaged" are also the least likely to talk about science with friends and acquaintances, to go to science events, and to read science books. The only non-mediated form of contact with science which is not significantly lower compared to the other segments are visits to zoos, aquariums, or botanical gardens.

5. Conclusion

Perceptions of science differ between sociodemographic groups. Segmentation analyses have the potential to focus on these differences and reconstruct latent patterns that divide populations into relatively similar groups. The study at hand provides such an analysis based on a representative survey of the Swiss population and adds to it from the perspective of the "science of science communication": in addition to reconstructing segments, it assesses whether people categorized into these segments exhibit specific patterns of media and information use.

The analysis shows that four segments can be reconstructed with different perceptions of science and that people in these segments inform themselves differently about science. Respondents in the predominantly male group of "*Sciencephiles*" with a strong interest and support for science, an extensive knowledge about it, and a pronounced belief in its potential use a wide variety of sources intensively, particularly the Internet. They evaluate media coverage of science positively and engage with such issues also in conversations, events, by reading science books and so on. The "*Critically Interested*," also with strong interest and support for science but with less trust in science's promises and a more pronounced critical view on the limits of science, use media and online sources similar to the "Sciencephiles" but are more cautious toward these sources. The "*Passive Supporters*," the largest group, with moderate levels of interest, trust and knowledge, and tempered but rather positive perceptions of science, use fewer sources, and less intensively, when it comes to science. For them, Wikipedia is particularly important. The least educated and predominantly female "*Disengaged*," making up the smallest segment, are not interested in science, have low scientific literacy, and harbor more critical views toward it—although their general assessment is still supportive. When they encounter scientific issues in mass media or online, which rarely happens, it is most likely on public TV or radio.

These findings can be used, first, to assess theoretical assumptions about perceptions of science and science communication. They reiterate, that different perceptions of and attitudes toward science converge in different population segments, and that these segments have different sociodemographic loci (e.g. OST and Wellcome Trust, 2000). The equally extensive scientific literacy of the "Sciencephiles" and "Critically Interested" segments demonstrates that knowledge does not determine support for science, further disconfirming the "deficit model" of science communication (e.g. Kawamoto et al., 2013). At the same time, the segments underscore relationships between attitudinal variables that have been established in other studies, for example, that interest in science, scientific literacy, and actively searching for information about science correlate positively (Ho et al., 2014).

Second, the results show that population segments differ also in their media repertoires. The results show that interest in and knowledge about science correlates with more frequent science-related information use (e.g. Nisbet et al., 2002). Moreover, segmentation studies are useful to monitor the degree of populations' fragmentation with regard to science-related attitudes and information patterns. Due to the changing media landscape, many scholars have warned that online and social media in which individuals configure their own information diets may lead to fragmented publics. Although such fragmentations seem to be less pronounced than expected for other issues (e.g. Fletcher and Nielsen, 2017), they could still be important for science and research—complex topics for which information is often acquired online (Brossard, 2013). Our study hints at such fragmentations, in which attitudinal patterns correspond to differences in information use. In turn, however, describing such differentiations in perceptions and information repertoires can be used for communication efforts, whether these aim at informing, image-building, or targeting attitudinal or behavioral change (cf. Detenber et al., 2016: 7374). Designing such efforts should take into account that target audiences may differ and that different aims, messages, and communicative channels need to be utilized (cf. Metag et al., 2017).

Third, the findings broaden the base of science-related segmentation data beyond the few countries for which such analyses have been done. In doing so, they demonstrate specifics of the Swiss case: despite clear attitudinal differences between the reconstructed segments, the results show that science is not a generally contentious issue in Switzerland. All segment groups are generally supportive of science, and there are no strong antagonists of science and research even though the "Critically Interested" or "Disengaged" may object to specific kinds of scientific research that, in their view, violates social, legal, or ethical norms (like animal testing, cf. Von Roten, 2013). This general support for science and research differs from countries like the United Kingdom (e.g. Research Councils, 2008) and may be due to Switzerland's status of a knowledge economy which invests strongly in research and education.

In addition, the results could also be interesting for analyses of the science–society nexus. In other fields, similar "segments have been validated as predictors of public support" for climate change–related policies, and in that respect, belonging to a certain segment proved to be a "stronger predictor than demographics and political ideology" (Detenber et al., 2016: 4738). Our results are in line with this observation. While we exclusively clustered along "psychographic" variables, the resulting differences in media and information use showed significant and recurring patterns across segments. A targeted effort of measuring the predictive value of segmentation analyses such as ours would certainly be worthwhile.

To do so, methodological advances would be helpful. Similar studies in other fields have employed discriminant analyses to identify the subsets of variables which best identify respondents' categorization into certain segments. On this basis, short survey instruments were developed (e.g. Maibach et al., 2011; Swim and Geiger, 2017) to enrich other studies and to test the value of the segmentation beyond a narrow field. This study would lend itself to the development of a short survey instrument.

Apart from survey studies, bolstering the segment descriptions by incorporating qualitative elements would be useful (cf. Hine et al., 2014). While standardized and partly tested survey tools exist to assess perceptions of science and the respective sources of information, details may remain hidden in such an analysis. For example, the "Sciencephiles" and the "Critically Interested," despite having differing perceptions of science, share a similar media diet with regard to science and research. Further elaboration could unearth important differences in their contact with science that go beyond general assessments of all science content. Eventually, given the considerable current changes in the relation between science and society (Fischhoff and Scheufele, 2013; Schäfer et al., 2015), it would certainly be worth to track potential changes in the makeup and size of the segments over time.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The "Wissenschaftsbarometer Schweiz" / "Science Barometer Switzerland" was funded by the Gebert Rüf Stiftung and the Stiftung Mercator Schweiz.

Notes

1. In marketing, segmentation analyses have been used to inform advertising and to influence consumer behavior and buying decisions (for overviews, see Yankelovich and Meer (2006) and Lotenberg et al. (2011)).

2. Cantons are federal entities in Switzerland similar to states in the United States.
3. These changes were cross-checked both with a recoded, traditional “correct–false” scale for all 11 questions and with a recoded version containing only those 5 questions which were taken verbatim from earlier studies. Our version of the science quiz correlated strongly with both other measures (r=.899, *p*<.01 and r=.723, *p*<.01), and the differences in knowledge about science between the segments which are reported below were similar across all quiz versions.
4. Before using latent class analysis, we also ran a factor analysis with a subsequent cluster analysis. It also resulted in a four-cluster solution with an interpretation similar to the one presented in this article.

References

Ajzen I (1989) Attitude structure and behavior. In: Pratkanis AR, Breckler SJ and Greenwald AG (eds) *Attitude Structure and Function*. Hillsdale, NJ: Lawrence Erlbaum Associates, pp. 241–274.

Ajzen I (2001) Nature and operation of attitudes. *Annual Review of Psychology* 52(1): 27–58.

Ajzen I (2002) Perceived behavioural control, self-efficacy, locus of control and the theory of planned behaviour. *Journal of Applied Social Psychology* 32: 665–683.

Bamberg S and Möser G (2007) Twenty years after Hines, Hungerford, and Tomera. *Journal of Environmental Psychology* 27(1): 14–25.

Bauer MW (2016) *The Culture of Science Indicators*. London: LSE.

BBVA Foundation (2011) *International Study on Scientific Culture*. Bilbao: BBVA.

Besley JC (2013) The state of public opinion research on attitudes and understanding of science and technology. *Bulletin of Science, Technology & Society* 33(1–2): 12–20.

Brossard D (2013) New media landscapes and the science information consumer. *Proceedings of the National Academy of Sciences of the United States of America* 110(Suppl 3): 14096–14101.

Brossard D and Scheufele DA (2013) Science, new media, and the public. *Science* 339(6115): 40–41. DOI: 10.1126/science.1232329.

Bucchi M. (2008). Of deficits, deviations and dialogues: Theories of public communication of science. In: Bucchi M and Trench B (eds) *Handbook of Public Communication of Science and Technology*. London: Routledge, pp. 57–76.

Detenber B, Rosenthal S, Liao Y and Ho S (2016) Audience Segmentation for Campaign Design: Addressing Climate Change in Singapore. *International Journal of Communication* 10: 4736–4758.

Dibb S and Simkin L (2009) *Bridging the Segmentation Theory/Practice Divide*. Abingdon: Taylor & Francis.

Engdahl E and Lidskog R (2014) Risk, communication and trust. *Public Understanding of Science* 23(6): 703–717.

Eurobarometer (2001) *Eurobarometer 55.2* “*Europeans, Science and Technology*.” Brussels: European Union.

Eurobarometer (2010) *Special Eurobarometer 340: Science and Technology*. Brussels: European Commission.

Eurobarometer S (2005) Europeans, science and technology. *European Commission*. June. Available at: http://ec.europa.eu/commfrontoffice/publicopinion/archives/ebs/ebs_224_report_en.pdf

Eveland WP (2001) The cognitive mediation model of learning from the news evidence from nonelection, off-year election, and presidential election contexts. *Communication Research* 28(5): 571–601.

Eveland WP Jr., Hutchens MJ and Shen F (2009) Exposure, attention, or “use” of news? *Communication Methods and Measures* 3(4): 223–244.

Fischhoff B and Scheufele DA (2013) The science of science communication. *Proceedings of the National Academy of Sciences of the United states of America* 110: 14031–14032.

Fletcher R and Nielsen RK (2017) Are people incidentally exposed to news on social media? *New Media & Society* 20(7): 2450–2468.

Fredin ES, Kosicki GM and Becker LB (1996) Cognitive strategies for media use during a presidential campaign. *Political Communication* 13(1): 23–42.

Gollwitzer M (2012) Latent-class-analysis. In: Moosbrugger H and Kelava A (eds) *Testtheorie Und Fragebogenkonstruktion*. Berlin and Heidelberg: Springer, pp. 295–323.

Guenther L and Weingart P (2017) Promises and reservations towards science and technology among South African publics. *Public Understanding of Science* 27(1): 47–58.
Hine DW, Reser JP, Morrison M, Phillips WJ, Nunn P and Cooksey R (2014) Audience segmentation and climate change communication. *Wiley Interdisciplinary Reviews: Climate Change* 5(4): 441–459.
Hurtado MC and Cerezo JAL (2012) Political dimensions of scientific culture. *Public Understanding of Science* 21(3): 369–384.
Kahlor L and Rosenthal S (2009) If we seek, do we learn? *Science Communication* 30(3): 380–414.
Kahlor L, Dunwoody S, Griffin RJ and Neuwirth K (2006) Seeking and processing information about impersonal risk. *Science Communication* 28(2): 163–194.
Kawamoto S, Nakayama M and Saijo M (2013) A survey of scientific literacy to provide a foundation for designing science communication in Japan. *Public Understanding of Science* 22(6): 674–690.
Kristiansen S, Bonfadelli H and Kovic M (2016) Risk perception of nuclear energy after Fukushima. *International Journal of Public Opinion Research* 30(1): 24–50.
Lee C-J, Scheufele DA and Lewenstein BV (2005) Public attitudes toward emerging technologies. *Science Communication* 27(2): 240–267.
Leiserowitz A, Maibach E, Roser-Renouf C, Feinberg G and Howe P (2013) *Global warming's six Americas, September 2012*. New Haven, CT: Yale Project on Climate Change Communication and George Mason University.
Leiserowitz A, Maibach E, Roser-Renouf C, Feinberg G, Rosenthal S and Myers T (2010) *Global Warming's Six Americas*. New Haven, CT: Yale University and George Mason University.
Linzer DA and Lewis JB (2011) poLCA: An R package for polytomous variable latent class analysis. *Journal of Statistical Software* 42(10): 1–29.
Lotenberg LD, Schechter C and Strand J (2011) Segmentation and targeting. In: Hastings G, Angus K and Bryant C (eds) *The SAGE Handbook of Social Marketing*. Berlin: Springer, pp. 125–135.
Macedo-Rouet M, Rouet J-F, Epstein I, et al. (2003) Effects of online reading on popular science comprehension. *Science Communication* 25(2): 99–128.
McLachlan G and Peel D (2004) *Finite Mixture Models*. Hoboken, NJ: John Wiley & Sons.
Magidson J and Vermunt J (2002a) Latent class models for clustering. *Canadian Journal of Marketing Research* 20(1): 36–43.
Magidson J and Vermunt J (2002b) Latent class models. In: Kaplan D (ed.) *The Sage Handbook of Quantitative Methodology for the Social Sciences*. Thousand Oaks, CA: SAGE, pp. 175–198.
Maibach EW, Leiserowitz A, Roser-Renouf C and Mertz CK (2011) Identifying like-minded audiences for global warming public engagement campaigns. *PLoS ONE* 6(3): e17571.
Maibach EW, Weber D, Massett H, et al. (2006) Understanding consumers' health information preferences development and validation of a brief screening instrument. *Journal of Health Communication* 11(8): 717–736.
Mejlgaard N and Stares S (2010) Participation and competence as joint components in a cross-national analysis of scientific citizenship. *Public Understanding of Science* 19(5): 545–561.
Metag J (2017) Rezeption und Wirkung öffentlicher Wissenschaftskommunikation [Use and Effects of Public Science Communication]. In: Bonfadelli H, Fähnrich B, Lüthje C, Milde J, Rhomberg M and Schäfer MS (eds) *Forschungsfeld Wissenschaftskommunikation* [The Field of Science Communication]. Berlin: Springer, pp. 251–274.
Metag J, Füchslin T and Schäfer MS (2017) Global warming's five Germanys: A typology of Germans' views on climate change and patterns of media use and information. *Public Understanding of Science* 26(4): 434–451.
Miller JD (1983) Scientific literacy: A conceptual and empirical review. *Daedalus* 112(2): 29–48.
Morrison M, Duncan R, Sherley C and Parton K (2013) A comparison between attitudes to climate change in Australia and the United States. *Australiasian Journal of Environmental Management* 20(2): 87–100.
National Science Board (2014) *Science and Engineering Indicators 2014*. Arlington, TX: National Science Foundation.

Nisbet M and Markowitz EM (2014) Understanding public opinion in debates over biomedical research. *PLoS ONE* 9(2): e88473.
Nisbet MC, Scheufele DA, Shanahan J, Moy P, Brossard D and Lewenstein BV (2002) Knowledge, reservations, or promise? *Communication Research* 29(5): 584–608.
Noar SM, Benac CN and Harris MS (2007) Does tailoring matter? Meta-analytic review of tailored print health behavior change interventions. *Psychological Bulletin* 133(4): 673–693.
OECD (2007) Revised fields of science and technology. Retrieved from http://www.oecd.org/science/inno/38235147.pdf
OST (2005) Science in society. London: Department of Trade & Industry, Office of Science and Technology.
OST and Wellcome Trust (2000) *Science and the Public*. London: Office of Science and Technology (OST) and Wellcome Trust.
Pardo R and Calvo F (2002) Attitudes toward science among the European public. *Public Understanding of Science* 11(2): 155–195.
Pardo R and Calvo F (2004) The cognitive dimension of public perceptions of science. *Public Understanding of Science* 13(3): 203–227.
Pew Research Center (2013) Public's knowledge of science and technology. Retrieved from http://www.people-press.org/2013/04/22/publics-knowledge-of-science-and-technology/
Prpic K (2011) Science, the public, and social elites. *Public Understanding of Science* 20(6): 733–750.
Research Councils UK (2008) *Public Attitudes to Science 2008*. London: Department of Innovation, Universities & Skills.
Roser-Renouf C, Maibach E, Leiserowitz A, et al. (2016) Faith, morality and the environment. Available at: http://climatecommunication.yale.edu/publications/faith-morality-environment
Rössler P (2011) *Skalenhandbuch Kommunikationswissenschaft* [Scale Handbook Communication Science]. Wiesbaden: Springer.
Schäfer MS (2009) From public understanding to public engagement: An empirical assessment of changes in science coverage. *Science Communication* 30(4): 475–505.
Schäfer MS (2012) Taking stock: A meta-analysis of studies on the media's coverage of science. *Public Understanding of Science* 21(6): 650–663.
Schäfer MS (2016) Mediated trust in science. *JCOM* 15: C02.
Schäfer MS (2017) Wissenschaftskommunikation online [Science Communication Online]. In: Bonfadelli H, Fähnrich B, Lüthje C, Milde J, Rhomberg M and Schäfer MS (eds) *Forschungsfeld Wissenschaftskommunikation* [The Field of Science Communication]. Berlin: Springer, pp. 275–293.
Schäfer MS and Taddicken M (2015) Mediatized opinion leaders. *International Journal of Communication* 9. Available at: http://ijoc.org/index.php/ijoc/article/view/2778
Schäfer MS, Kristiansen S and Bonfadelli H (2015) Wissenschaftskommunikation im Wandel [Changes in Science Communication]. In: Schäfer MS, Kristiansen S and Bonfadelli H (eds) *Wissenschaftskommunikation im Wandel* [Changes in Science Communication]. Köln: Hherbert Von Halem Verlag, pp. 10–42.
Slater MD (1996) Theory and method in health audience segmentation. *Journal of Health Communication* 1(3): 267–284.
Sütterlin B, Brunner TA and Siegrist M (2011) Who puts the most energy into energy conservation? *Energy Policy* 39(12): 8137–8152.
Swim JK and Geiger N (2017) From alarmed to dismissive of climate change. *Environmental Communication* 11(4): 568–586.
Tsfati Y, Cohen J and Gunther AC (2011) The influence of presumed media influence on news about science and scientists. *Science Communication* 33(2): 143–166.
Vermunt JK and Magidson J (2016) *Technical Guide for Latent GOLD 5.1*. Belmont, MA: Statistical Innovations.
Von Roten FC (2013) Public perceptions of animal experimentation across Europe. *Public Understanding of Science* 22(6): 691–703.
Wind Y (1978) Issues and advances in segmentation research. *Journal of Marketing Research*: 317–337.

Wissenschaft im Dialog (2015) Wissenschaftsbarometer [Science Barometer]. Available at: http://www.wissenschaft-im-dialog.de/projekte/wissenschaftsbarometer/

Yankelovich D and Meer D (2006) Rediscovering market segmentation. *Harvard Business Review* 84(2): 122–131.

Author biographies

Mike S. Schäfer is professor for science communication at the University of Zurich's Department of Communication and Media Research (IKMZ) and Director of the university's Center for Higher Education and Science Studies (CHESS). His research focuses on science communication and climate change communication, particularly online.

Tobias Füchslin is a Research and Teaching Associate at the University of Zurich's Department of Communication and Media Research (IKMZ). His research focuses on science communication, scientific and digital literacies, and information seeking.

Julia Metag is professor for communication science at the University of Fribourg's Department of Communication and Media Research (DCM), Switzerland. Her research focuses on political communication, science communication, and media effects.

Silje Kristiansen is a Swiss National Science Foundation (SNSF) Postdoctoral Fellow at Northeastern University at the College of Arts, Media and Design and Associate Editor of Environmental Communication. Her research interests are risk communication, environmental communication, and science communication.

Adrian Rauchfleisch is a Senior Research and Teaching Associate at the University of Zurich's Department of Communication and Media Research (IKMZ). His research focuses on political communication, online communication, and science communication.

7.2 Metag et al. (2018)

Between Active Seekers and Non-Users: Segments of Science-related Media Usage in Switzerland and Germany.

Metag, J., Maier, M., Füchslin, T., Bromme, L., & Schäfer, M. S.

This article was originally published in:

Metag, J., Maier, M., Füchslin, T., Bromme, L., & Schäfer, M. S. (2018). Between Active Seekers and Non-Users: Segments of Science-related Media Usage in Switzerland and Germany. *Environmental Communication*, *28*(4), 1–18. https://doi.org/10.1080/17524032.2018.1463924

ENVIRONMENTAL COMMUNICATION
2018, VOL. 12, NO. 8, 1077–1094
https://doi.org/10.1080/17524032.2018.1463924

RESEARCH ARTICLE

Between Active Seekers and Non-Users: Segments of Science-related Media Usage in Switzerland and Germany

Julia Metag [a], Michaela Maier[b], Tobias Füchslin[c], Laurits Bromme[b] and Mike S. Schäfer[c]

[a]Department of Communication and Media Research DCM, University of Fribourg, Fribourg, Switzerland; [b]Department of Communication and Media Psychology, University of Koblenz-Landau, Landau, Germany; [c]IKMZ – Department of Communication and Media Research, University of Zurich, Zürich, Switzerland

ABSTRACT

Citizens' attitudes toward science are related to their use of science-related information from various sources. Evidence is scarce regarding citizens' individual media repertoires for staying informed about science as segmentation studies so far have primarily focused on scientific attitudes. In this paper, we explore audience segments regarding their science-related information behavior and whether such segments are comparable or vary between two countries with similar information environments. Based on two surveys in Switzerland and Germany, we identify national audience segments that differ in their science-related information repertoires, and analyze their sociodemographic characteristics and science-related attitudes. In both countries, we find very comparable information user segments ranging from those who inform themselves frequently about science ("Active Seekers"/"Science Consumers") to those who hardly get in contact with any information about science and research ("Non-Users"). Those segments which get in contact with information about science frequently show generally more positive attitudes.

ARTICLE HISTORY
Received 8 December 2017
Accepted 1 April 2018

KEYWORDS
Information use; segmentation; survey; science communication; Switzerland; Germany

Introduction

Science is seemingly full of wonders: Researchers explore the origins of the universe, aim to cure terminal diseases, engineer human DNA, work on better ways to curtail greenhouse gas emissions, etc. Today, science is understood as being contextualized in society and often being co-produced by scientists with partners from economy, politics, civil society, etc. (e.g. Jasanoff, 2007). Science thus forms an integral part of our society with scientists, economic, and political actors as well as citizens, among others, taking up important roles when the societal support for science is concerned. For example, science depends on the support of political authorities for scientists' freedom to pursue the research questions that they regard as important. And it depends on tax payers' acceptance of expenditures and liberties, and on their general support for science.

Latest research has shown that citizens' support for science strongly depends on their interest, trust, and general (positive) attitudes toward research (Besley, 2016). These aspects are, again, strongly related to science communication, as many citizens (i.e. people who do not have personal contacts with the system of science) mainly encounter science via communication, for example in news media, online, in social media, in museums, participating in science cafes, or other science-related events. Science communication research analyzes how citizens acquire information about science, its processes, and findings, and in how far this information is relevant for the formation

CONTACT Julia Metag julia.metag@unifr.ch
Supplemental data for this article can be accessed at http://dx.doi.org/10.1080/17524032.2018.1463924.

of their science-related attitudes (for a summary see, e.g. Maier, Rothmund, Retzbach, Otto, & Besley, 2014). However, when it comes to the question of which sources citizens use to stay informed about ongoing research, evidence is more scarce, especially with regard to individual media repertoires. Thus, the question which individual combination of journalistic offline and online media, online sources, or social media citizens use to gather science-related information, has become even more pressing in times of online communication in which the monopoly of science journalism has long vanished (e.g. Büchi, 2017; Jia, Wang, Miao, & Zhu, 2017; Schäfer, 2017; Su, Scheufele, Bell, Brossard, & Xenos, 2017). Yet, segmentation studies in science communication so far have primarily focused on audience segments with regards to scientific attitudes (Kawamoto, Nakayama, & Saijo, 2013; OST, 2005; OST & Wellcome Trust, 2000; Research Councils UK, 2008; Rothmund et al., 2017; Schäfer, Füchslin, Metag, Kristiansen, & Rauchfleisch, 2018). In some of these studies, we find first evidence that these segments also show distinct patterns of information behavior (e.g. Guenther & Weingart, 2018; Kawamoto et al., 2013). However, these studies either do not focus specifically on science-related information (Kawamoto et al., 2013) or only integrate a limited number of information sources (Guenther & Weingart, 2018). Therefore, in this paper, we contribute to research on citizens' science-related information behavior in four ways: For the first time, we aim at identifying audience segments that differ in their science-related information repertoires, taking news media sources, their online equivalents, but also other online sources and social media into account. By focusing on citizens' general science-related information repertoires, we gain insight into segments of overall science media use which are more generalizable and not limited to a certain scientific topic which individuals might be especially interested in (e.g. climate change, GMO). We thus deliver insights into the general ways in which citizens get information and orientation about scientific issues, which may feed into their overall perceptions of science as a social system, and into their systemic trust (Schäfer, 2016). Second, we analyze the sociodemographic characteristics of these audience segments, and, third, investigate whether they differ in their science-related attitudes. Fourth, we compare these structures in two countries, i.e. Germany and Switzerland, applying a most similar cases design to overcome the specificity of one nation state and test the generality of information segments across countries (Esser & Hanitzsch, 2012). Such studies comparing audience structures in similar and varying information environments are missing in the field of science information usage so far.

The relevance of science information user segments

Distinguishing different segments of the population – like different types of media users – has a long tradition in social science (Smith, 1956). Commonly, this was done via segmentation analyses that aimed to "divide the general public into relatively homogeneous, mutually exclusive subgroupings" (Hine et al., 2014, p. 442; cf. Lotenberg, Schechter, & Strand, 2011, p. 125). These analyses had also often the intent to develop tailored communication strategies with which attitudes and behaviors of these subgroups could be influenced subsequently (Slater, 1996).

Segmentation analyses have used three general logics for the selection of relevant variables and the identification of audience segments or user types: Early approaches often used sociodemographic and geographic location variables to identify audience segments (Slater, 1996). The audience segments that were reconstructed in this way were later compared with regards to their media use, their attitudes or their consumer behavior (Dibb & Simkin, 2009). Such an approach is only useful in those rare cases, however, when sociodemographic or sociogeographic variables are strongly linked to attitudinal or behavioral patterns (Yankelovich & Meer, 2006, 123f.).

Therefore, some of the recent studies based their segmentation analyses on peoples' attitudes toward a certain object, i.e. on "psychographic" variables (Wind, 1978, 319f.). These incorporated cognitive elements like knowledge, affective elements as well as behavioral elements of attitudes (e.g. Hine et al., 2014; Schäfer et al., 2018; Sütterlin, Brunner, & Siegrist, 2011).

These segmentation analyses have drawn criticism as well, however. Scholars have argued that while psychographically rooted analyses "may capture some truth about real people's lifestyles, attitudes, self-images and aspirations, [they] are weak at predicting peoples' behavior" (Yankelovich & Meer, 2006, p. 124) and thus segmentation analyses should be based on behavioral variables (Yankelovich & Meer, 2006), for example around peoples' patterns of media and information use (cf. Lotenberg et al., 2011). After all, identifying population segments that are homogenous in their patterns of media and information use would have the potential to improve communication efforts and to facilitate better-targeted messages (Noar, Benac, & Harris, 2007).

Audience segments, sociodemographic differences, and attitudes toward science

What segments of citizens exist with regards to science-related information use? The studies by Kawamoto et al. (2013) and Guenther and Weingart (2018) identified different segments of the Japanese and South African populations with regards to their attitudes toward science, sociodemographics, *and* their media use. By including media use in their segmentation analyses, they could show that certain segments of the public use information about science significantly more than others (e.g. the "Sciencephiles" in Japan; Kawamoto et al., 2013; or the "Urban, moderately to high literate, and highly educated" in South Africa; Guenther & Weingart, 2018). These studies, however, either do not include specific science-related information use but only general news usage (Kawamoto et al., 2013), or do not segment the public solely or even primarily based on their science-related media and information use and include only a limited number of information sources (Guenther & Weingart, 2018; Kawamoto et al., 2013). However, only if one identifies audience segments based on their scientific media and information use one is able to differentiate information repertoires in the public (cf. Hasebrink & Popp, 2006) and to provide information for science advocates which helps them improve their communication efforts. The reconstruction of segment-specific combinations of media and information sources is particularly relevant in times of individualized content selection and curation.

As of now, such studies, which have segmented the population according to their media and information use, only exist for issues other than science, mostly general news use. A recent study found that the German public can be divided into four segments with regards to their information use (Mangold, Vogelgesang, & Scharkow, 2017). One segment focuses on traditional and particularly regional news media, the second one relies on entertainment-oriented media, the third on quality media, i.e. public-service broadcasting and broadsheets, and the fourth on online media in its news diet (Mangold et al., 2017). A study in Switzerland found similar segments, among them such which rely more on traditional, offline mass media, and segments that are strongly oriented toward online media, such as the "Global Surfers" (Schneider & Eisenegger, 2016). The Swiss study also showed that audience segments not only differ with regards to the kind of news media they use, but also with regards the frequency of their overall news use. Also, they found the segment of the "News Deprived," i.e. of people who use news media considerably less frequently than all other segments (Schneider & Eisenegger, 2016).

We assume that the general patterns related to the use of traditional mass media versus online media and to the frequency of use also apply to science-related information use. We can thus derive two hypotheses with regards to our first research aim:

> H1a: Audience segments of science information use will differ with regard to whether they use more traditional journalistic mass media or more online media.

> H1b: Audience segments of science information use will differ with regards to the frequency of their overall use of scientific information.

However, apart from these general tendencies of online and offline science media use, audience segments of science information use may reveal more nuanced differences than segments of general news use. There are many possibilities for people to inform themselves about science – ranging from general news media, which also cover science issues, to specific science magazines. Particularly on the Internet, the information sources available are very diverse. The media ecosystem with regards to science has changed particularly strongly because science journalism today faces major challenges (e.g. economically; Schäfer, 2017) and online media has altered the landscape for information about science in general (Brossard, 2013).

In addition, we expect to find sociodemographic differences between people belonging to different science-related information user segments as previous studies have established a link between sociodemographic characteristics and patterns of media and information use (e.g. Nisbet et al., 2002). With regards to age, a German survey found that older people more often use scientific content in print media or on television but are less likely to look for it on the Internet (Wissenschaft im Dialog, 2016). Research also established gender differences with women using all kinds of media less often than men (Nisbet et al., 2002). In Germany, women were less likely to watch television shows about science and or to get information about science on the Internet (Wissenschaft im Dialog, 2016). Education positively influences newspaper use, science magazine, and science television use, and the use of the Internet and social media in countries like the US, Germany, and South Korea (Chang, Kim, Kang, Shim, & Ma, 2017; Nisbet et al., 2002; Wissenschaft im Dialog, 2016). Based on these findings, we expect the following differences:

> H2a: Audience segments that use primarily online communication about science are on average younger than segments using primarily traditional mass media.

> H2b: Audience segments that use primarily online communication about science include on average less women than segments using primarily traditional mass media.

> H2c: Audience segments with intensive use of science information across all kinds of media are higher educated than segments with lower science information use.

As a third step, we investigate whether the audience segments differ in their science-related attitudes. As the segmentation analyses by Kawamoto et al. (2013) and Guenther and Weingart (2018) have shown, attitudes toward science and science-related media use are correlated. Audience segments with a higher interest in science, higher scientific literacy, and belief in the benefits of science are also the ones getting in contact with it through online and offline media most frequently. This is underscored by most of the media effects research in science communication revealing that media use in general can increase individuals' interest in science and also, to a certain degree, their scientific literacy (Nisbet et al., 2002; Zhao, 2009). Media use about scientific issues is also related to positive attitudes toward science, support for specific scientific developments as well as trust in science (Anderson, Scheufele, Brossard, & Corley, 2012; Dudo et al., 2011; Nisbet et al., 2002; Scheufele & Lewenstein, 2005). On this basis, we hypothesize:

> H3: Audience segments with a more frequent use of scientific information across all channels are more interested in science, more scientific literate and hold more positive attitudes towards science.

Media coverage of science in Switzerland and Germany

The fourth aim of this paper is to initiate research on the question whether such audience segments are universal or vary, e.g. depending on information environments, a strand missing in science communication research so far. As a first step, we compare the structures in two similar countries, i.e. Switzerland and Germany. Such a most similar cases design is appropriate to overcome the specificity of one nation state and to test the generality of the information segments (Esser & Hanitzsch, 2012; Livingstone, 2003). To test whether the two countries qualify for a most similar cases design, we compare not only their general media systems but also the characteristics of the two national information environments with regards to science-related information.

In general, the media structures in both countries can be best described by the characteristics of the so-called democratic corporatist model (Hallin & Mancini, 2004), e.g. having (still) relatively high newspaper circulations, a pluralist national press with strong professionalization, self-regulation, and press freedom as well as strong public-service broadcasting. Also, Mejlgaard (2017, p. 8) has described science as "central" for the science-society relationship in both countries, with consolidated science communication, inclusion of publics in the governance of science and transfer of scientific findings to policy-makers.

Regarding the relevance of science coverage within both media systems, we look at the number of journalists active in the field, the amount and tone of media coverage devoted to science, and the share of audience. The "Worlds of Journalism" project (Hanusch & Hanitzsch, 2017) shows that about 4% of journalists in both countries work for science and education desks in their media (Dingerkus, Keel, & Wyss, personal information; Steindl, Lauerer, & Hanitzsch, 2017). Looking at the attention general media grant to science topics, we find for both countries that, e.g. public broadcasters, allocate between 3% and 6% of their total airtime to "culture and science" (fög, 2017; Reitze, 2016). Of course, science topics make up a considerable portion of the print market (e.g. books) and attract the attention of up to 10% of newspaper readers in both countries alike (fög, 2017; Reitze, 2016). However, weighted for the total reach of newspapers, the numbers converge to the figure of about 5% of the media coverage and usage in both countries being devoted to and attracted by science topics.

Regarding journalists' self-assessed motives and roles, findings show that Swiss and German journalists alike find objectivity of reporting to be their most important goal ($m_{\text{Switzerland}} = 4.53$; $m_{\text{Germany}} = 4.59$; $p > .05$; see Dingerkus, Keel, & Wyss, 2016, p. 2; Hanitzsch et al., 2016, p. 2; also see Kristiansen, Schäfer, & Lorencez, 2016). And concerning the tonality of coverage of science topics, which seems to be neutral to slightly positive in general, the few analyses at hand suggest that there is probably more variation regarding the evaluation of specific scientific topics than between the general coverage of science in the two countries under observation (Eisenegger & Gedamke, 2013; Hömberg & Yankers, 2000; Milde & Ruhrmann, 2006).

In sum, Switzerland and Germany seem appropriate for a most similar cases study as the science-related media coverage in both countries and its usage are similarly pronounced. In addition, (science) journalists in both countries appear to hold similar perceptions of their own roles which seem to lead to a usually neutral to slightly positive tone of the media reports on science-related topics. Therefore, we hypothesize:

H4: Segments of science-related media usage will be similar in Switzerland and Germany.

Methods

Data

In the case of Switzerland, we will use data from a telephone survey conducted in 2016 by the market research institute Demoscope. It assesses citizens' information behavior as well as attitudes toward, beliefs in, and knowledge about science. The sample was based on a random quota sampling procedure. First, telephone numbers were drawn randomly from all listed numbers of private households (including 5% mobile phone numbers). Second, quotas for age and gender combined were used to select participants. One thousand and fifty-one respondents participated (651 in German-, 200 in French-, and 200 in Italian-speaking Switzerland). Fifty-one percent were women, the mean age was 46 years ($SD = 17.9$) and 27% had a university degree (see also Table 1). For the analyses, the sample was weighted regarding cantons, size of living area, education, occupation, and household size.

For Germany, we draw on data from an online survey on citizens' science-related information behavior and attitudes fielded in 2016 as part of the DFG special priority program 1409 "Science and the Public." The sample consists of 1997 respondents recruited by the private sampling provider

Table 1. Overview of measures.

	Switzerland				Germany			
	Items	*N*	*M*	SD	Items	*N*	*M*	SD
Media sources								
How often do you …	get in contact with science and research via television?	1036	2.75	1.01	watch reports about science and research on television?	1986	2.82	0.85
	get in contact with science and research via newspapers or magazines?	1042	3.28	1.22	read articles about scientific topics in newspapers or magazines?	1978	2.49	0.96
	get in contact with science and research via the science pages of a newspaper or science magazines?	1032	1.95	1.28	read the science pages of a newspaper or science magazines?	1985	2.10	0.96
How often do you get in contact with science and research via …	Online outlets of newspapers and magazines	1042	2.23	1.33		1977	2.23	1.05
	Online archives of television and radio channels	1039	1.90	1.14		1977	2.29	1.01
	Institutional websites (scientific, government, organizations)	1041	2.31	1.28		1970	2.09	0.91
	Facebook (DE: and other social media networks)	1044	1.55	1.06		1978	2.33	1.21
	Blogs or message boards	1042	1.54	0.90		1975	1.86	0.93
	Wikipedia	1040	2.72	1.40		1977	2.61	1.08
	YouTube or similar video platforms	1043	2.22	1.29		1979	2.28	1.04
Other contacts with science and research								
How often do you do one of the following …	Visit museums and exhibitions covering science and research	1049	2.47	1.08		1988	2.02	0.85
	Visit zoos, aquariums or botanical gardens	1050	2.71	1.13		1992	2.54	0.83
	Attend events, talks, discussions concerning science and research	1050	2.09	1.09		1989	1.70	0.81
	Read nonfiction books on science and research	1051	2.51	1.28		1986	1.92	0.91
	Watch movies related to science and research in the cinema	1049	2.32	1.18		1967	2.60	0.85
	Talk about science and research with friends and acquaintances	1051	3.11	1.12		1986	2.46	0.92
Scale format for all items	1 = "never" … 5 = "very often")				(1 = "never" … 4 = "very often")			
Sociodemographics								
Age	Years	1051	46.33	17.90		1997	44.65	13.94
Gender	Percent female	1051	50.76			1997	49.97	
Education	Percent university education	1046	27.2			1997	15.77	
Political orientation	(1 = "left" … 7 = "right")	998	3.64	1.28	(1 = "left" … 11 = "right")	1779	5.55	2.15

Religiosity	(1 = "not at all religious" … 5 = "very religious")	1047	2.72	1.25	"I would describe myself as a religious" (1 = "not agree at all" … 4 = "completely agree")	1974	1.88	0.98
Proximity to science[2]	Index: 0–4	1049	1.59	1.26	Index: 0–4	1896	0.74	0.97
Attitudes toward Science and research								
Interest in science	How interested are you in science and research? (1 = "not at all" … 5 = "very interested")	1044	3.14	1.19	"I would describe myself as interested in science." (1 = "not agree at all" … 4 = "completely agree")	1910	2.91	0.80
Scientific literacy	Index: 0–8 Calculated from 8 "true" or "false" statements (e.g. Electrons are smaller than atoms.)	1051	5.95	1.47	Index: 0–8 Calculated from 8 "true" or "false" statements (e.g. Electrons are smaller than atoms)	1997	5.39	1.77
How high is your trust in … ?	science in general	1042	3.58	0.74		1899	2.98	0.59
	scientists from universities	1042	3.69	0.79		1894	3.09	0.65
	scientists from private corporations	1041	3.13	0.90		1886	2.45	0.78
Format of trust scales	1 = "very low" … 5 = "very high")				1 = "very low" … 4 = "very high")			

Note: The German item wording is only displayed, when differing from the Swiss version.

Respondi and represents the German adult population concerning age, gender, education, and region (Schäfer, 2017). The average age was 45 years (SD = 14.0), 50% were female, and 16% had a university degree (see also Table 1). The German sample was drawn from an online panel but participants in the panel were recruited online and offline. As participants for the Swiss study were recruited offline, while the German sample was recruited online and offline, the results might be biased in the sense that online media usage might be overestimated in Germany. This has to be taken into account when interpreting the findings. Regarding sociodemographic variables, both samples are representative for their respective country and possible differences should not affect the overall patterns of science information repertoires.

Measurements

We used various measures of media and information usage on which we base our segmentation analysis (an overview of all measures and their descriptives can be found in Table 1). In both countries, the frequency of use of traditional media for information about science (television, newspapers/magazines, and science magazines) as well as the usage of different online channels are included in the segmentation analysis (e.g. BBVA Foundation, 2011; Pew Research Center, 2013).

In order to enrich the description of the identified segments, we analyzed to what extent participants get in contact with science on other occasions such as visits in museums, zoos, aquariums, science-related events, or through nonfiction books (e.g. OST & The Wellcome Trust, 2001). We also describe segments with regards to their sociodemographic characteristics (age, sex, and education, see Besley, 2013), religiosity (OST & The Wellcome Trust, 2001), political orientation (Nisbet et al., 2002), and an index of people's personal or professional proximity to science (BBVA foundation, 2011). Furthermore, we measured interest in science (e.g. Eurobarometer, 2010), scientific literacy, and trust in science (Lee, Scheufele, & Lewenstein, 2005; for all these variables see also Table 1) as attitudinal variables. People's scientific literacy was calculated as a sum index consisting of eight true/false questions. We assigned one point for correct answers, for wrong or no answers, people were attributed zero points.

The continents on which we live have been moving for millions of years. (correct)
Electrons are smaller than atoms. (correct)
Antibiotics kill viruses as well as bacteria. (false)
The genes of the mother decide if the child will be a boy or a girl. (false)
Sunscreen protects the skin from ultraviolet rays. (correct)
[*German survey: Sunscreen protects the skin from infrared rays. (false)*]
Water boils faster in high altitudes. (correct)
It is possible to change the genes of human embryos. (correct)
[*German survey: It is not yet possible to change the genes of human embryos. (false)*]
Scientific theories never change. (false)

Logic of analysis

To identify population segments, we ran separate latent class analyses (LCAs) in both countries. LCA has several advantages: Unlike most distance-based methods, it can handle any variable level, large numbers of variables (Magidson & Vermunt, 2004; McLachlan & Peel, 2005), and also single missing values (Maibach, Weber, Massett, Hancock, & Price, 2006). Since cluster solutions are based on a statistical model, measures to compare model fit such as BIC can be used and the predictive power of indicators is denoted (Linzer & Lewis, 2011).

For each country, we used 10 media source variables and computed optimized segment-solutions from 1 up to 10[1] segments using LatentGold 5.1 software (Vermunt & Magidson, 2016). For each model, we entered 5000 random sets of starting values into the algorithm to ensure validity and robustness of each solution. All further specifications are available within the Supplemental

Materials. The final solutions were determined by first looking at BIC values, then taking face validity of segment profiles into account. To assess group means, modal attribution was used to assign individual cases to segments according to their maximum likelihood estimation.

Results

User segments in Switzerland and Germany

For the *Swiss* public, BIC values pointed to five segments as the most favorable solution, closely followed by six and four segments (see Supplemental Materials). As the five-segment solution also offered a clear interpretation, we chose it as our solution for Switzerland (see Figure 1 below and Table 3 of the Supplemental Materials).

In order to estimate the precision of classification, we calculated the overall hit rate. It is defined as the sample mean of all respondents' modal posterior probabilities (cf. Gollwitzer, 2012). For the Swiss sample, the hit rate was $T = 0.81$. For 99% of cases, the likelihood of belonging to one of the five segments exceeded 40% and no single case was indecisive.

- The "Active Seekers" ($n = 152$, 14.49%) form the smallest segment of the Swiss population. They get in contact with science-related information most frequently across all kinds of media. They use news media regularly but are also the most avid readers of science magazines. On the Internet, they look for reputable sources of information by using websites of scientific institutions and Wikipedia most often. Also, Youtube channels are being used quite regularly by members of this segment. This information pattern indicates that people in this segment probably search quite actively for information about science offline (e.g. in science magazines), but particularly online.
- The "Mass Media Users" ($n = 262$, 24.96%) are the largest segment of the Swiss population and similar to the "Active Seekers" in their information patterns with regards to traditional media. They use traditional mass media quite regularly to get information about science. However, with regards to their patterns of online media use about science and research, they differ from

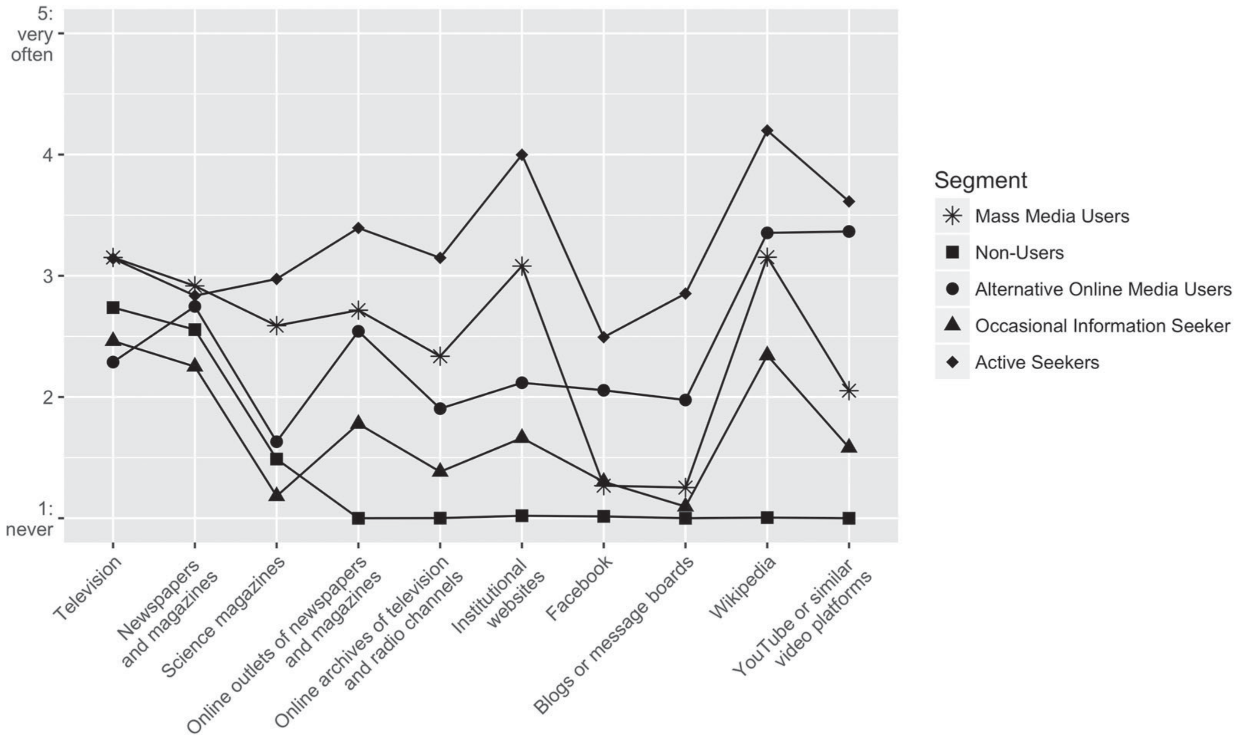


Figure 1. Segments of science information users in Switzerland.

the "Active Seekers." They use online media considerably less as their use of Facebook, blogs, or Youtube is among the lowest of the five segments. If they use online sources at all, their focus is on websites of scientific institutions, Wikipedia, and news media outlets online.

- People in the "Alternative Online Media Users" segment ($n = 221$, 21.02%) do not get in contact with science in traditional media that often. When they do, they use newspapers (online and offline) for information about science; however, they barely use specific outlets focusing on science such as magazines. At the same time, their use of online media differs from the other segments. Their use of mainstream online media sources is not so pronounced but they use alternative channels of information on the Internet instead. People belonging to this segment get in contact with information about science and research when using Wikipedia and Youtube.
- The fourth segment, the "Occasional Information Seeker" ($n = 191$, 18.19%), only sporadically gets information about science when they use TV or print media. Their use of online media about science is at a comparatively low level. If at all, they use Wikipedia to look up information. However, compared to the other segments, even the use of Wikipedia is at a lower level.
- Compared to all the other segments, the "Non-Users" ($n = 224$, 21.34%) hardly get into contact with information about science and research. Strikingly, the second largest segment of the Swiss population does not get in contact with information about science in online media at all. They get in touch with scientific information when they use television and traditional print media – their science media use patterns completely belong to the offline world, likely as a by-product of habitual media use.

For *Germany*, identifying the best fitting model was more complicated: Although the BIC pointed to a 10-segment model as the preferred choice (see Supplemental Materials), that particular solution was difficult to interpret. The six-segment model – as well as all higher models – already raised several questions regarding the explanatory value of its segments: For one, they strongly differed in size, with the smallest one covering only 9% of the respondents (5% in the higher models); for another, their profiles were almost indistinguishable and resulted in identical interpretations. We therefore opted for the five-segment solution, which had reasonable population shares (15–27%) and five distinct profiles (see Figure 2 below and Table 3 of the Supplemental Materials). The hit

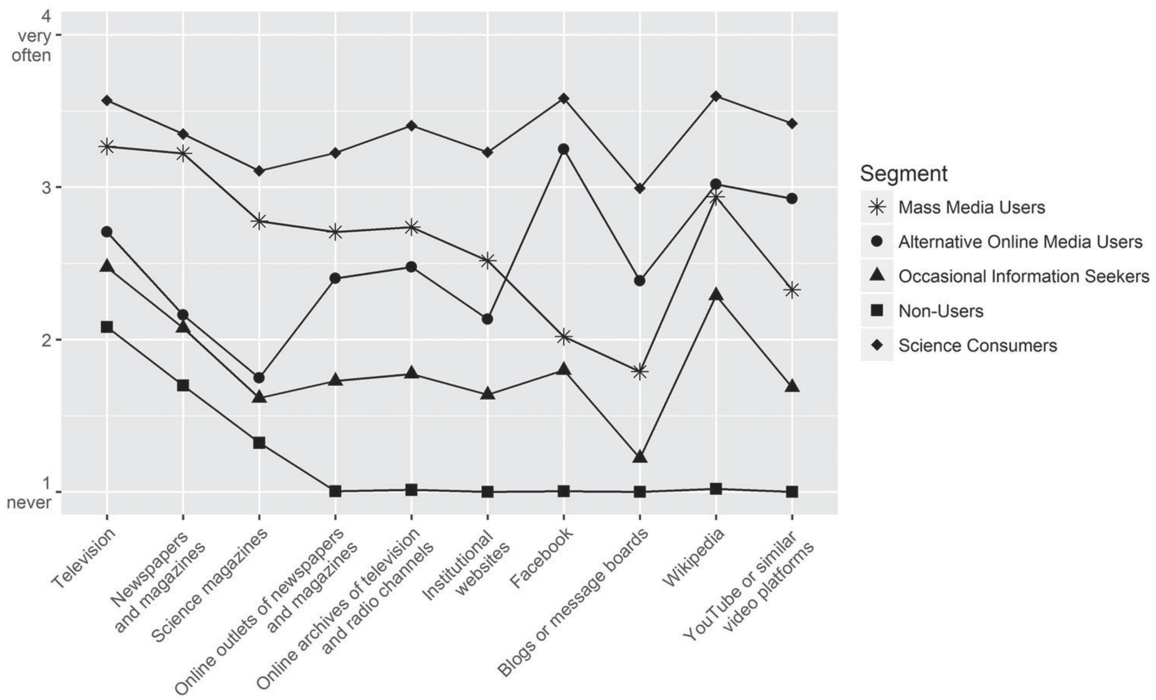


Figure 2. Segments of science information users in Germany.

rate of this segmentation was $T = 0.85$ (cf. Gollwitzer, 2012) and for 99% of the cases, the posterior probability exceeded 40%. No single case was indecisive.

- We could identify a segment of "Science Consumers" ($n = 293$, 14.7%). Similar to the "Active Seekers" in Switzerland, this segment shows the highest use of scientific information across all media channels, including online communication. However, compared to the Swiss "Active Seekers," people in this segment also clearly have the highest contact with science through traditional mass media. In addition, their use of Facebook for scientific information is strong, also constituting a difference from the "Active Seekers" in Switzerland who use Wikipedia and Youtube more often than social networks.
- The second segment is the "Mass Media Users" ($n = 478$, 23.94%). They also show generally high levels of science information use but they get in contact with scientific issues primarily via television and print media more than via online media. If they look for scientific information online, they do so in online outlets of newspapers or online archives of television and radio channels or on websites of scientific institutions, for which they yield the second highest scores within the German public.
- In contrast to the "Mass Media Users," the segment of the "Alternative Online Media Users" ($n =$ 478, 23.92%) is more oriented toward the use of information about science on the Internet. While they do not get in contact with scientific information that often through traditional mass media, they are much more active online, especially using alternative information sources. They yield the second highest scores for the use of Facebook, Wikipedia, Youtube, and blogs. Facebook is even their most frequently used source of information.
- We also find a segment of "Occasional Information Seekers" in Germany ($n = 433$, 21.68%). People in this segment show average patterns of information use with regard to science. They occasionally get in contact with science through television and online media at a lower level. They almost never get in contact with scientific information through blogs but they use Wikipedia from time to time.
- The last segment of the German population is also the "Non-Users" ($n = 315$, 15.77%). Like in Switzerland, German citizens in this segment do not use online media for scientific information at all. If they get in contact with information about science, it is through television.

Since we find five segments in both countries, which are very much comparable (see also Figure 3), we find some initial evidence for Hypothesis 4. What is more, these segments differ in their frequency of overall information use about science with the "Active Seekers"/"Science Consumers" being the ones informing themselves about science most regularly, thus supporting Hypothesis 1b. The segments can also be distinguished with regards to their use of offline and online media. The fact that we find segments such as the "Alternative Online Media Users" and the "Mass Media Users" lends support to Hypothesis 1a.

Sociodemographic and attitudinal characteristics of the segments

The identified segments in both countries differ with regards to sociodemographics and science-related attitudes (Table 2 and Figure 3). In both countries, the "Active Seekers" and "Science Consumers" are highly educated, have a relatively high scientific literacy and the highest trust and interest in science, thus corroborating Hypotheses 2c and 3. Also, with regards to contact with science and research on other occasions (e.g. visits to museums and zoos), these segments yield the highest scores in both countries. In the segment of the "Non-Users," we find in both countries considerably more women than men, and the level of education is the lowest compared to all other segments in both countries. This corresponds to a low level of scientific literacy. People in this segment also trust science the least, have the lowest interest, and are least likely to get in contact with science and research at other occasions (e.g. visiting museums, etc.).

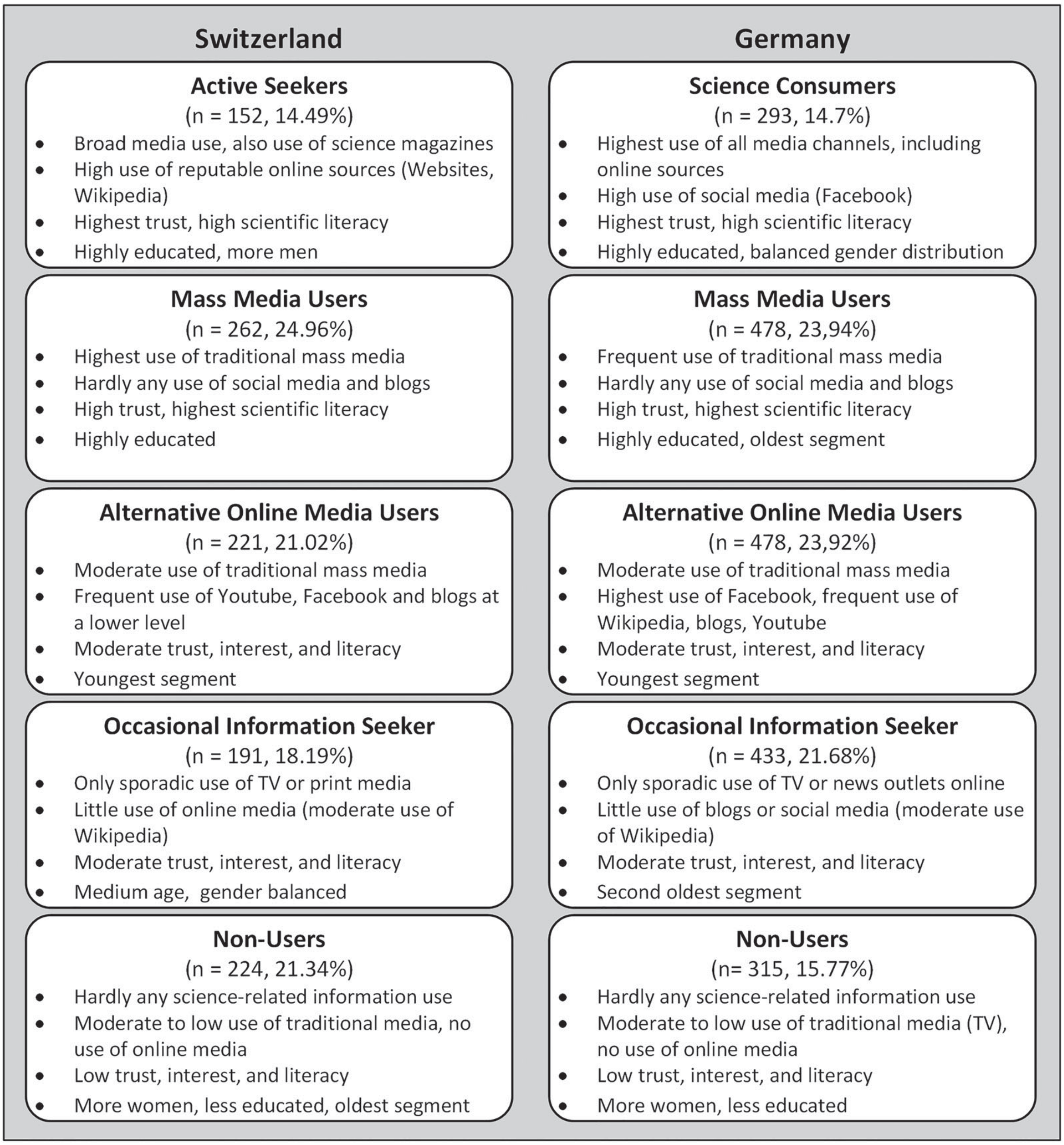


Figure 3. Overview of science-related information user segments in Switzerland and Germany.

The other segments are positioned between the "Active Seekers"/"Science Consumers" and the "Non-Users" with regards to their sociodemographics and attitudes toward science. The "Mass Media Users" in Switzerland and Germany are quite similar to the "Active Seekers"/"Science Consumers" in that they are highly educated and show high scientific literacy. The "Alternative Online Media Users" are the youngest segment on average. This lends support to Hypothesis 2a. Instead, we do not find evidence for Hypothesis 2b, as the "Alternative Online Media Users" are balanced in gender. Apart from these similarities, we also recognize some differences in the sociodemographic characteristics and attitudes toward science between the German and Swiss segments. In Switzerland, "Non-Users" are the oldest segment, while in Germany, the "Mass Media Users" are the oldest overall. In Switzerland, the "Non-Users" are the most religious on average, which is not the case in Germany. Figure 3 provides an overview of all segments in Switzerland and Germany and their distinct media repertoires, attitudes toward science, and sociodemographic characteristics.

Table 2. Sociodemographics and attitudes toward science of the segments.

	Switzerland					Germany				
	Active seekers	Mass media users	Alternative online media users	Occasional info seekers	Non-Users	Science consumer	Mass media users	Alternative online media users	Occasional info seekers	Non-Users
Cluster size (estimated by mean posterior probabilities)	152.29	262.37	220.88	191.20	224.25	293.46	478.06	477.67	432.96	314.84
	14.49%	24.96%	21.02%	18.19%	21.34%	14.70%	23.94%	23.92%	21.68%	15.77%
Sociodemographics										
Age	39.58	50.05	35.9	46.82	55.64	42.91	47.49	40.28	46.82	45.60
Gender (percent female)	35.69%	45.63%	53.91%	51.30%	63.47%	51.02%	44.32%	50.59%	45.06%	63.41%
University education	33.70%	37.61%	22.32%	30.57%	11.99%	16.19%	20.13%	17.17%	15.81%	6.60%
Political orientation	3.6	3.61	3.5	3.68	3.79	5.33	5.38	5.54	5.84	5.65
Religiosity	2.48	2.71	2.52	2.76	3.03	2.03	1.97	1.86	1.79	1.77
Proximity to science	2.05	1.99	1.52	1.46	1	1.13	1.03	0.72	0.51	0.31
Attitudes toward science										
Interest	4.03	3.81	3.23	3.2	3.04	3.44	3.26	2.98	2.85	2.45
Scientific literacy	6.03	6.39	5.97	5.98	5.35	5.59	5.78	5.54	5.34	4.46
Trust in scientists from universities	3.88	3.88	3.72	3.61	3.4	3.22	3.22	3.06	3.05	2.81
Trust in scientists from private corporations	3.31	3.27	3.11	3.09	2.92	2.61	2.45	2.38	2.42	2.40
Trust in science in general	3.81	3.73	3.53	3.47	3.38	3.12	3.07	2.95	2.95	2.77
Other contacts with science and research										
Museums and exhibitions	2.99	2.84	2.37	2.24	1.99	2.67	2.38	1.99	1.68	1.37
Zoos, aquariums or botanical gardens	2.8	2.81	2.53	2.73	2.66	2.99	2.71	2.52	2.27	2.27
Events, talks, discussions	2.65	2.6	2	1.67	1.55	2.50	1.96	1.66	1.29	1.17
Nonfiction books	3.33	3	2.42	2.04	1.86	2.86	2.33	1.82	1.53	1.13
Movies	2.85	2.35	2.48	2.09	1.98	3.18	2.82	2.62	2.34	2.04
Talk with friends and acquaintances	3.75	3.38	3.23	2.81	2.5	3.23	2.85	2.54	2.11	1.49

Discussion

Our study demonstrates that segments of the population can be distinguished with regards to their science-related information use, thus providing evidence about people's media repertoires for science. We find a spectrum of information user segments ranging from those who inform themselves frequently and actively about science and research ("Active Seekers"/"Science Consumers") to those who hardly get in contact with information about science at all ("Non-Users"). In between, there are segments which receive information about science and research through their habitual media use or sporadically inform themselves ("Occasional Information Seekers"). What is more, audience segments differ with regard to their preference of online or offline media, or, more precisely, mainstream or alternative sources of information. The "Alternative Online Media Users" retrieve specific online media, among them social media and blogs, more than all the other segments (with the exception of the "Science Consumers"). The "Mass Media Users" do not refrain from using online media, but they use established and journalistic sources on the Internet more often than alternative sources like social media. Overall, the study shows that audience segments of science communication which we find in one country, i.e. Switzerland, can be found almost equally in another country, i.e. Germany, which is very similar in its media system and with regards to media coverage about science and science journalism.

In both countries, the segments are also very similar with regards to their sociodemographics and attitudes toward science. Their media use is reflected in their attitudes toward science – those segments which get in contact with information about science and research frequently show generally more positive attitudes. We also find well-established trends with regard to the sociodemographic profiles of the segments. Those segments, which actively inform themselves about science ("Active Seekers"/"Science Consumers"), are more highly educated. The "Alternative Online Media Users" are also the youngest segment on average (Nisbet et al., 2002).

However, we also find some nuanced differences between the two countries. In Germany, Facebook is a much more common source for information about science than in Switzerland. For the "Alternative Online Media Users" in Germany, it is even the most important information source. It has to be noted though that this can also be due to the fact the German sample relied on an online panel. At the same time, Youtube seems to play a greater role in the online environment for scientific information in Switzerland.

The general differences between the audience segments replicate what has been found for general news media use (e.g. Mangold et al., 2017; Schneider & Eisenegger, 2016). Some segments are more inclined toward online media use while others lean more toward traditional mass media. However, if one takes a deeper look at the findings, they also reveal that there are differences between audience segments of general news media use and audience segments of science information use. The significance of Wikipedia for almost all segments is something that is not found when audience segments of general news use are concerned. The relevance of Wikipedia for science communication has been also established in other studies (e.g. Segev & Sharon, 2017). In addition, institutional websites play a less important role in citizens' information repertoires when they inform themselves about everyday or political news. That the segments identified in this study are science-specific is underscored by the fact that science magazines constitute one of the distinguishing variables. There is a clear difference in the use of science magazines between the "Active Seekers"/"Science Consumers" and "Mass Media Users" compared to the other three segments in both countries. This exemplifies the relevance of special interest media for scientific information. We can compare our findings to the clusters found by Guenther and Weingart (2018) in South Africa although they did not conduct their analysis solely based on media use variables. They found two clusters which use scientific information frequently. People belonging to the "Urban, moderately literate and moderately educated" cluster use mostly television and could be roughly compared to the "Mass Media Users" in Germany and Switzerland (Guenther & Weingart, 2018). The other group "Urban, moderately to high literate, and highly educated" also frequently use the Internet but it is not clear what exactly they use online.

Thus, we cannot establish whether they are comparable to the “Alternative Online Media Users” since those rely on non-journalistic online sources such as Youtube. Therefore, our study allows for a more detailed analysis of the science-specific media use since it incorporates various online channels.

The characteristics of the audience segments have some implications for science communication. First, the segment of the “Non-Users” is quite large in Switzerland, and of considerable size in Germany. There is a significant part of the population in both countries which rarely or never gets in contact with science-related media content. Since this is combined with little interest and lower education, the question is how to reach this segment of the public. If the “Non-Users” get in contact with information about science and research at all, this happens through traditional journalistic mass media, namely television and newspapers or magazines. This underlines that traditional science journalism is still important since those who do not search for information about science actively at least get in touch with it through their habitual media use.

Second, the other important result of our segmentation analysis is that online media play an important role for audiences. The “Alternative Online Media Users” entails between 21% and 24% of the population in both countries. A significant number of people use scientific information which has not, or only partly, passed the journalistic quality criteria. This raises the question how science should deal with this situation. On the one hand, this is an opportunity for science communicators since they can reach a large part of the audience directly. On the other hand, they also have to deal with the risk that these people encounter information online which they think are scientific but may include pseudo-scientific information (Schäfer, 2017). Science communicators thus need to develop strategies to deal with this, for example, by cooperating with other partners in the educational sector. This study provides a first basis for such strategic considerations by outlining what media are used by different audience segments.

Third, although the “Active Seekers” in Switzerland generally use scientific information very regularly, their frequent use of Wikipedia could pose a problem to science communicators. If even the “Active Seekers” look for scientific information most frequently on Wikipedia, the question is how science communicators may reach these people, who are highly interested in science and probably open to their messages, with targeted information.

Fourth, one has to keep in mind that science media use is also driven by people’s motives why they use specific media outlets. For science communicators, it is not only relevant what kind of information repertoires exist in the public but also what the drivers behind the various kinds of media use are. Only if they know whether citizens use certain science media for information, entertainment, habitual use, or one of the many other motives, they gain a better understanding on how to reach these segments. Future studies could thus build upon this study and highlight what motives drive which audience segments.

Comparing audience segments in two countries with very similar media systems and similar structures regarding science communication, we aimed at overcoming the specificity of one nation state. Our hypothesis that similar communication environments should yield similar audience structures finds general support. However, this analysis is only a first step in the attempt to link science communication structures and science information usage and needs to be extended to other countries and cultures. In this vein, it will be especially necessary to analyze the relevance of alternative online media, which operate independently from the formal media and information systems and are accessible for users across countries with the potential to create online audience segments independent from geographic boundaries. Of course, the ongoing development of online communication and related changes in patterns of usage should also be observed on a longitudinal basis.

And last, it is well possible that science information usage is dependent on (1) aspects of specific scientific topics or domains, (2) individual factors on the side of the recipient as well as (3) interactions of both types of variables. For example, controversial scientific issues could spark more intense and diversified media use in general. Also, one can easily imagine that someone is an “Active Seeker” or “Science Consumer” when it comes to a specific scientific topic which she/he is particularly interested in or affected by (e.g. with regards to health issues). At the same time, this person may belong to the segment of the "Non-Users" when other scientific topics are concerned which she/he has no interest in. Our segmentation analysis cannot account for such differences regarding topics nor intra-individual preferences. However, by looking at general science information use it is able to provide information on audience segments which are valuable for providers of a broad spectrum of science information, e.g. mass media but also actors in the educational sector.

Related to this limitation of the study, although we identify the different science information repertoires of the public, we cannot say anything about how the use of a certain type of channel is interrelated with the use of other information sources from a procedural perspective and on an individual basis. For example, it is possible that individuals get in contact with a scientific issue through mass media coverage and subsequently look for more information about this issue on Wikipedia.

Notes

1. In the case of Germany, we went up to 14 segments, since 10 segments were not enough to draw a clear conclusion regarding the optimal number of segments (see Supplemental Materials).
2. Respondents were first asked whether they were scientists themselves. If not, they were asked whether they "personally knew a scientist," "have family members that study or studied at university level," or "come in contact with science through their work." Each affirmative answers resulted in one index-point. Scientists were directly assigned four points, resulting in a sum index ranging from 0 to 4.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Deutsche Forschungsgemeinschaft (1409 "Science and the Public"); Gebert Rüf Stiftung [grant number GRS-025/15]; and Stiftung Mercator Schweiz [grant number 2014-0607].

ORCID

Julia Metag http://orcid.org/0000-0003-4328-6419

References

Anderson, A. A., Scheufele, D. A., Brossard, D., & Corley, E. A. (2012). The role of media and deference to scientific authority in cultivating trust in sources of information about emerging technologies. *International Journal of Public Opinion Research*, *24*(2), 225–237. doi:10.1093/ijpor/edr032

BBVA Foundation. (2011). *International study on scientific culture: Understanding of science*. Bilbao: BBVA.

Besley, J. C. (2013). The state of public opinion research on attitudes and understanding of science and technology. *Bulletin of Science, Technology & Society*, *33*(1–2), 12–20.

Besley, J. C. (2016). The national science foundation's science and technology survey and support for science funding, 2006–2014. *Public Understanding of Science*. Advance online publication. doi:10.1177/0963662516649803

Brossard, D. (2013). New media landscapes and the science information consumer. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(Suppl. 3), 14096–14101. doi:10.1073/pnas.1212744110

Büchi, M. (2017). Microblogging as an extension of science reporting. *Public Understanding of Science*, *26*(8), 953–968. doi:10.1177/0963662516657794

Chang, J.-H., Kim, S.-H., Kang, M.-H., Shim, J. C., & Ma, D. H. (2017). The gap in scientific knowledge and role of science communication in South Korea. *Public Understanding of Science*. Advance online publication. doi:10.1177/0963662516685487

Dibb, S., & Simkin, L. (2009). Bridging the segmentation theory/practice divide. *Journal of Marketing Management*, *25*(3–4), 219–225. doi:10.1362/026725709X429728

Dingerkus, F., Keel, G., & Wyss, V. (2016). *Country report: Journalists in Switzerland* (World of Journalism Study). Retrieved from urn:nbn:de:bvb:19-epub-30991-7.
Dudo, A., Brossard, D., Shanahan, J., Scheufele, D. A., Morgan, M., & Signorielli, N. (2011). Science on television in the 21st century. *Communication Research*, *38*(6), 754–777. doi:10.1177/0093650210384988
Eisenegger, M., & Gedamke, S. (2013). Wissenschaft in den Medien. Zur Logik medialer Wissenschaftsvermittlung. *medien & zeit*, *28*(4), 34–45.
Esser, F., & Hanitzsch, T. (2012). On the why and how of comparative inquiry in communication studies. In F. Esser & T. Hanitzsch (Eds.), *Handbook of comparative communication research* (pp. 3–22). New York, NY: Routledge.
Eurobarometer. (2010). *Special eurobarometer 340: Science and technology*. Brussels: European Commission.
fög – Forschungsinstitut Öffentlichkeit und Gesellschaft / Universität Zürich. (2017). *Jahrbuch 2017: Qualität der Medien*. Basel: Schwabe Verlag.
Gollwitzer, M. (2012). Latent-class-analysis. In H. Moosbrugger & A. Kelava (Eds.), *Springer-Lehrbuch. Testtheorie und Fragebogenkonstruktion* (2nd ed., pp. 295–323). Berlin: Springer.
Guenther, L., & Weingart, P. (2018). Promises and reservations towards science and technology among South African publics: A culture-sensitive approach. *Public Understanding of Science*, *27*(1), 47–58. doi:10.1177/0963662517693453
Hallin, D. C., & Mancini, P. (2004). *Comparing media systems: Three models of media and politics. Communication, society and politics*. Cambridge: Cambridge University Press.
Hanitzsch, T., Steindl, N., & Lauerer, C. (2016). *Country report: Journalists in Germany* (World of Journalism Study). Retrieved from urn:nbn:de:bvb:19-epub-28095-3.
Hanusch, F., & Hanitzsch, T. (2017). Comparing journalistic cultures across nations. *Journalism Studies*, *18*(5), 525–535. doi:10.1080/1461670X.2017.1280229
Hasebrink, U., & Popp, J. (2006). Media repertoires as a result of selective media use. A conceptual approach to the analysis of patterns of exposure. *Communications*, *31*(3), 369–387.
Hine, D. W., Reser, J. P., Morrison, M., Phillips, W. J., Nunn, P., & Cooksey, R. (2014). Audience segmentation and climate change communication: Conceptual and methodological considerations. *Wiley Interdisciplinary Reviews: Climate Change*, *5*(4), 441–459. doi:10.1002/wcc.279
Hömberg, W., & Yankers, M. (2000). Wissenschaftsmagazine im Fernsehen. Exemplarische Analysen öffentlich-rechtlicher und privater Wissenschaftssendungen. *Media Perspektiven*, *12*, 574–580. Retrieved from http://www.ard-werbung.de/fileadmin/user_upload/media-perspektiven/pdf/2000/12-2000_Hoemberg.pdf
Jasanoff, S. (2007). *Designs on nature: Science and democracy in Europe and the United States*. Princeton, NJ: Princeton University Press.
Jia, H., Wang, D., Miao, W., & Zhu, H. (2017). Encountered but not engaged: Examining the use of social media for science communication by Chinese scientists. *Science Communication*, *39*(5), 646–672. doi:10.1177/1075547017735114
Kawamoto, S., Nakayama, M., & Saijo, M. (2013). A survey of scientific literacy to provide a foundation for designing science communication in Japan. *Public Understanding of Science*, *22*(6), 674–690. doi:10.1177/0963662511418893
Kristiansen, S., Schäfer, M. S., & Lorencez, S. (2016). Science journalists in Switzerland: Results from a survey on professional goals, working conditions, and current changes. *Studies in Communication Sciences*, *16*, 132–140. doi:10.1016/j.scoms.2016.10.004
Lee, C.-J., Scheufele, D. A., & Lewenstein, B. V. (2005). Public attitudes toward emerging technologies: Examining the interactive effects of cognitions and affect on public attitudes toward nanotechnology. *Science Communication*, *27*(2), 240–267.
Linzer, D. A., & Lewis, J. B. (2011). poLCA: An R package for polytomous variable latent class analysis. *Journal of Statistical Software*, *42*(10), 1–29. doi:10.18637/jss.v042.i10
Livingstone, S. (2003). On the challenges of cross-national comparative media research. *European Journal of Communication*, *18*(4), 477–500.
Lotenberg, L. D., Schechter, C., & Strand, J. (2011). Segmentation and targeting. In G. Hastings, K. Angus, & C. Bryant (Eds.), *The sage handbook of social marketing* (pp. 125–135). Thousand Oaks, CA: SAGE.
Magidson, J., & Vermunt, J. (2004). Latent class models. In D. Kaplan (Ed.), *The sage handbook of quantitative methodology for the social sciences* (pp. 175–198). Thousand Oaks, CA: SAGE.
Maibach, E. W., Weber, D., Massett, H., Hancock, G. R., & Price, S. (2006). Understanding consumers' health information preferences: Development and validation of a brief screening instrument. *Journal of Health Communication*, *11*(8), 717–736. doi:10.1080/10810730600934633
Maier, M., Rothmund, T., Retzbach, A., Otto, L., & Besley, J. C. (2014). Informal learning through science media usage. *Educational Psychologist*, *49*(2), 86–103. doi:10.1080/00461520.2014.916215
Mangold, F., Vogelgesang, J., & Scharkow, M. (2017). Nachrichtennutzung in Deutschland. *Eine nutzerzentrierte Repertoireanalyse. Medien & Kommunikationswissenschaft*, *65*(4), 704–723. doi:10.5771/1615-634X-2017-4-704
McLachlan, G. J., & Peel, D. (2005). *Finite mixture models. Wiley series in probability and statistics applied probability and statistics section*. New York, NY: Wiley.

Mejlgaard, N. (2017). Science's disparate responsibilities: Patterns across European countries. *Public Understanding of Science*. Advance online publication. doi:10.1177/0963662517724645

Milde, J., & Ruhrmann, G. (2006). Molekulare Medizin in deutschen TV-Wissenschaftsmagazinen. Ergebnisse von Journalisteninterviews und Inhaltsanalysen. *Medien & Kommunikationswissenschaft*, *54*(3), 430–456.

Nisbet, M. C., Scheufele, D. A., Shanahan, J., Moy, P., Brossard, D., & Lewenstein, B. V. (2002). Knowledge, reservations, or promise? A media effects model for public perceptions of science and technology. *Communication Research*, *29*(5), 584–608. doi:10.1177/009365002236196

Noar, S. M., Benac, C. N., & Harris, M. S. (2007). Does tailoring matter? Meta-analytic review of tailored print health behavior change interventions. *Psychological Bulletin*, *133*(4), 673–693.

OST, & the Wellcome Trust. (2001). Science and the public: A review of science communication and public attitudes toward science in Britain. *Public Understanding of Science*, *10*(3), 315–330.

OST, & Wellcome Trust. (2000). *Science and the public: A review of science communication and public attitudes to science in Britain*. London: The Office of Science and Technology (OST) & Wellcome Trust.

OST. (2005). *Science in society: Findings from qualitative and quantitative research*. London: Department of Trade & Industry, Office of Science and Technology.

Pew Research Center. (2013). *Public's knowledge of science and technology*. Retrieved from http://www.people-press.org/2013/04/22/publics-knowledge-of-science-and-technology/

Reitze, H. (2016). *Media Perspektiven: Basisdaten 2016*. Retrieved from http://www.ard-werbung.de/fileadmin/user_upload/media-perspektiven/Basisdaten/Basisdaten_2016_Inhalt_komplett_verlinkt.pdf

Research Councils UK. (2008). *Public attitudes to science 2008: A survey*. London: Department of Innovation, Universities & Skills.

Rothmund, T., Bromme, L., Bender, J., Maier, M., Gollwitzer, M., Kienhues, D., & Bromme, R. (2017, May 25–29). *Identifying subpopulations of science-related attitudes across topics*. Presentation at the 67th Annual Conference of the International Communication Association (ICA), San Diego, CA, USA.

Schäfer, M. S. (2016). Mediated trust in science. Concept, measurement and perspectives for the "science of science communication". *JCOM – Journal of Science Communication*, *15*(5), C02.

Schäfer, M. S. (2017). How changing media structures are affecting science news coverage. In K. H. Jamieson, D. M. Kahan, & D. A. Scheufele (Eds.), *Oxford library of psychology. The Oxford handbook on the science of science communication* (pp. 51–57). New York, NY: Oxford University Press.

Schäfer, M. S., Füchslin, T., Metag, J., Kristiansen, S., & Rauchfleisch, A. (2018). The different audiences of science communication. A segmentation analysis of the Swiss population's perceptions of science and their information and media use patterns. *Public Understanding of Science*. Advance online publication. doi:10.1177/0963662517752886

Scheufele, D. A., & Lewenstein, B. V. (2005). The public and nanotechnology: How citizens make sense of emerging technologies. *Journal of Nanoparticle Research*, *7*(6), 659–667. doi:10.1007/s11051-005-7526-2

Schneider, J., & Eisenegger, M. (2016). *Wie Mediennutzer in die Welt schauen. Die Newsrepertoires der Schweizerinnen und Schweizer und ihre Themenagenden*. Basel: Schwabe Verlag Basel (Studien Qualität der Medien, v.22016).

Segev, E., & Sharon, A. J. (2017). Temporal patterns of scientific information-seeking on Google and Wikipedia. *Public Understanding of Science (Bristol, England)*, *26*(8), 969–985. doi:10.1177/0963662516648565

Slater, M. D. (1996). Theory and method in health audience segmentation. *Journal of Health Communication*, *1*(3), 267–283. doi:10.1080/108107396128059

Smith, W. R. (1956). Product differentiation and market segmentation as alternative marketing strategies. *Journal of Marketing*, *21*(1), 3–8.

Steindl, N., Lauerer, C., & Hanitzsch, T. (2017). Journalismus in Deutschland. *Publizistik*, *62*(4), 401–423. doi:10.1007/s11616-017-0378-9

Su, L. Y.-F., Scheufele, D. A., Bell, L., Brossard, D., & Xenos, M. A. (2017). Information-sharing and community-building: Exploring the use of Twitter in science public relations. *Science Communication*, *39*(5), 569–597. doi:10.1177/1075547017734226

Sütterlin, B., Brunner, T. A., & Siegrist, M. (2011). Who puts the most energy into energy conservation? A segmentation of energy consumers based on energy-related behavioral characteristics. *Energy Policy*, *39*(12), 8137–8152. doi:10.1016/j.enpol.2011.10.008

Vermunt, J., & Magidson, J. (2016). *Technical guide for latent GOLD 5.1: Basic, advanced, and syntax*. Belmont: Statistical Innovations.

Wind, Y. (1978). Issues and advances in segmentation research. *Journal of Marketing Research*, *15*(3), 317–337.

Wissenschaft im Dialog. (2016). *Wissenschaftsbarometer 2016: Ergebnisse nach Subgruppen*. Retrieved from https://www.wissenschaft-im-dialog.de/fileadmin/user_upload/Projekte/Wissenschaftsbarometer/Dokumente_16/Wissenschaftsbarometer2016_nachSubgruppen.pdf

Yankelovich, D., & Meer, D. (2006). Rediscovering market segmentation. *Harvard Business Review*, *84*(2), 122–131. 166.

Zhao, X. (2009). Media use and global warming perceptions. *Communication Research*, *36*(5), 698–723. doi:10.1177/0093650209338911

7.3 Füchslin et al. (2019)

Who wants to be a citizen scientist? Identifying the potential of citizen science and target segments in Switzerland.

Füchslin, T., Schäfer, M. S., & Metag, J.

This article was originally published in:

Füchslin, T., Schäfer, M. S., & Metag, J. (2019). Who wants to be a citizen scientist? Identifying the potential of citizen science and target segments in Switzerland. *Public Understanding of Science (Bristol, England)*, *28*(6), 652-668. https://doi.org/10.1177/0963662519852020

Theoretical/research paper

P | U | S

Public Understanding of Science
2019, Vol. 28(6) 652–668

DOI: 10.1177/0963662519852020
journals.sagepub.com/home/pus
SAGE

Who wants to be a citizen scientist? Identifying the potential of citizen science and target segments in Switzerland

Tobias Füchslin and Mike S. Schäfer
University of Zurich, Switzerland

Julia Metag
Université de Fribourg, Switzerland

Abstract

Driven by the proliferation of digital media, citizen science – the involvement of non-scientists in scientific research – represents one of the most important recent developments in science communication as it brings science and the public closer together. So far, however, citizen science projects have mostly attracted people that are highly educated, mostly male and already have very positive attitudes towards science. Based on nationally representative survey data ($N = 1051$), our study explores the potential of citizen science in Switzerland. Using regression analysis, we show that attitudes towards science are significant antecedents of respondents' interest in participating in citizen science – but that gender and education are not. In addition, latent class analysis identifies five segments, representing over one-third of the Swiss population, who are interested in citizen science and could potentially be engaged: 'Free-Timers', 'Senior Sciencephiles', 'Young Sciencephiles', 'Intrigued Adolescents' and 'Fully Employed Parents'. Additional description suggests that previously overlooked segments are best addressed online via YouTube or offline in zoos or botanical gardens. Overall, our analysis suggests that citizen science's potential is far higher than previous projects were able to realize.

Keywords

citizen science, science attitudes and perceptions, science communication, survey, Switzerland

1. Introduction, relevance and research question

Science and society have moved closer together in recent decades. This mutual approximation has been described as scientific knowledge production moving from 'mode 1' to 'mode 2' (Gibbons

Corresponding author:
Tobias Fuechslin, Department of Mass Communication and Media Research, University of Zurich, Andreasstr 15, Zurich CH-8050, Switzerland.
Email: t.fuechslin@ikmz.uzh.ch

et al., 1994) or towards ‘contextualized science’ (Nowotny et al., 2001), or as a general ‘societalization’ of science (Weingart, 2001). The emergence and rise of digital media and particularly of online and social media have catalysed this approximation in recent years. They have established new interfaces between science and society (Dickel and Franzen, 2016) that allow non-scientists to interact with science in novel ways – or at least to considerably scale up opportunities for interaction even though they may have existed before: non-scientists can now be witnesses to ‘science in the making’ in livestreams from the NASA control room or Twitter feeds from scientific conferences. They can be discussion partners of scientists in online boards and fora (e.g. Zavestoski et al., 2016). They can be watchdogs in post-publication peer review online, or on plagiarism Wikis (e.g. Fähnrich et al., 2015). They can finance science via crowdfunding (e.g. Schäfer et al., 2016). And they can participate in research by becoming citizen scientists.

Citizen science (CS) – the involvement of non-scientists in scientific research – has been described as ‘perhaps the most dramatic development in science communication in the last generation’ (Lewenstein, 2016). Although early forms of citizen participation date back to the 17th century (Miller-Rushing et al., 2012), online media have moved CS to new heights. Including citizens in scientific research projects has become common practice in many fields, such as astronomy, biology and ecology (Kullenberg and Kasperowski, 2016), with more than 1400 projects listed on CS platform SciStarter (2018) alone. For scientists as well as many societal stakeholders, CS holds strong promises: By utilizing crowd resources, CS enables researchers to tackle amounts of data and analysis that would otherwise be unattainable (Nature, 2015). It promises positive effects on participants’ scientific literacy and attitudes towards science (Bonney et al., 2009). More generally, CS is seen as a way to ‘democratize’ science by incorporating many – and many diverse – participants in the research process, thus strengthening the bond between science and society (Irwin, 1995).

Some of these promises have already turned out to be true. Many CS projects have been realized and resulted in thousands of academic publications (Kullenberg and Kasperowski, 2016). Project evaluations indicate that CS projects can indeed increase participants’ scientific knowledge as well as their attitudes towards science and research (Bonney et al., 2016; Pandya and Dibner, 2018). When it comes to including many, and many diverse, citizen scientists in the respective projects, however, CS seems to have reached its boundaries. Studies unveil that volunteers for CS projects are mostly male, highly educated and display favourable attitudes towards science before their participation already (Curtis, 2018; Haklay, 2018). Fittingly, Bonney et al. (2016) conclude that ‘if the field of citizen science is to truly contribute to democratizing science, then it must strive to reach a wider range of audiences and participants (p. 12)’.

Two factors might stop project organizers from reaching a more diverse set of participants and, thus, realizing CS’s full potential: it could be that they are either not aware of certain groups’ interest in CS, or that project organizers are not adequately reaching or addressing those interested (West and Pateman, 2016). To this date, it remains an open question how large the overall potential of CS is, which factors shape people’s participation and how a wider circle of participants could be mobilized (Lewenstein, 2016).

Questions regarding peoples’ interest in participation, the factors behind this interest and the best ways to address them cannot be answered by analysing participants of CS projects themselves, as such samples are subject to a strong selection bias. Nationally representative samples, however, provide a robust basis to answer these questions. Therefore, our study analyses nationally representative survey data from Switzerland – a country that has seen an increase in domestic CS projects and is building an infrastructure to become one of the world’s main players in CS (Science et Cité, 2015). Based on these data, we aim to identify the overall potential of CS in the country.

The analysis is guided by three research questions: we first identify potential participants by comparing people with very low to people with very high degrees of interest in CS and analysing the general characteristics that shape their potential participation, asking,

(RQ1) What characteristics predict people's intention to participate in CS projects in Switzerland?

Afterwards, we focus on ways to improve the likelihood to reach potential participants for CS in Switzerland by addressing the two potentially limiting factors: not being aware of or inadequately addressing target groups. We identify specific segments within the subset of the population that displays a general willingness to participate in CS (*RQ*2) and analyse ways to address these segments by describing them in terms of their topical interests and the communication channels that are most likely to reach them (*RQ*3).

(RQ2) Among Swiss citizens interested to participate in CS, which segments can be differentiated?

(RQ3) What are the best ways to address the segments with regard to their topical interests and commonly used communication channels?

2. Literature review

Participation in CS projects can be broken down into stages. For volunteerism in general, Penner (2002) proposed to differentiate between the decision to volunteer, the first volunteering actions (initial volunteerism), and long-term engagement (sustained volunteerism). Using this heuristic, a considerable number of studies have analysed people's motivations *during* their participation in CS projects (Curtis, 2018). Our study, however, focuses on the previous stage in which people decide whether to participate in CS.

As we show in the following, previous research has barely addressed this stage, and therefore, scholars are unclear about the factors that shape participation in CS (Lewenstein, 2016: 1). When aiming to identify such factors, however, it is still useful to survey previous scholarship about online and offline CS projects.

On one hand, presentations and evaluations of *online* CS projects often contain participant descriptions based on survey data. These descriptions mostly focus on sociodemographic factors and people's interests. Curtis (2018) delivers a comprehensive overview and summary of characteristics of people that participate in online CS. She concludes that 'the available data suggests that the typical participant is likely to be a well-educated male with an existing interest in science or computing' (Curtis, 2018: 168). Based on her own data, she also noticed that respondents 'demonstrate a wider interest in science and report taking part in science-related activities such as reading popular science books, visiting science centres, and looking at science-related websites' (Curtis, 2018: 60).

On the other hand, it is useful to look at *offline* CS projects as well. Although there are no summaries similar to Curtis (2018) available for offline CS projects, the characteristics of participants from recent studies also seem to indicate that they are mostly men (Alender, 2016; Land-Zandstra et al., 2016) and highly educated (Alender, 2016; Land-Zandstra et al., 2016; Lynch et al., 2018). What many studies show additionally is that participants have a high interest in science or the more specific project topic, as well as very positive attitudes towards science (Dean et al., 2018; Lynch et al., 2018). When it comes to people's age, results are more varied, ranging from samples mainly consisting of retired people (Alender, 2016) to more balanced examples (Dean et al., 2018).

A recent analysis of 68 online and offline CS projects representing a total sample of 65,336 participants confirms the unequal participation patterns observed in other studies, concluding that 'there were striking patterns in the reported participant demographics which generally described a slightly male-biased, overwhelmingly white, and well-educated population with somewhat of a tendency to have previously participated in other projects' (Pandya and Dibner, 2018: 143).

Sample descriptions make clear that CS projects seem strongly affected by 'participation inequality' (Haklay, 2018). It is noteworthy, however, that studies' descriptions of CS participants online and offline are biased by self-selection in two ways: they only describe people who participated in a CS project and who additionally opted to participate in a survey. Any analysis of CS participants, however, is unable to assess whether CS has reached its boundaries or whether it could attract other potential participants. Only a general population sample can answer such questions. So far, only one study used such a general sample with a 'focus on potential volunteers for marine citizen science rather than only volunteers who have already been recruited in citizen science projects' (Martin, 2017: 143) – but this study was limited to a specific setting and topic. For coastal Australia, Martin (2017) looked at 1145 marine users (i.e. fishers, divers, beach users, etc.) and ascertained their willingness to participate in CS. While this study suggests that people with more positive attitudes towards science are more willing to participate and invest hours in CS projects, the role of sociodemographic factors remains unexplored. Furthermore, the study was not representative of the whole country and seemed to survey a highly forthcoming part of the population in which only six respondents - i.e. 0.5% of all respondents - were not interested in helping scientific research.

3. Methodology

Data

We ran a secondary analysis of a nationally representative data set – the 'Science Barometer Switzerland' ('Wissenschaftsbarometer Schweiz') – from 2016 that ascertained the Swiss' willingness to partake in scientific research projects (for an overview see Schäfer et al., 2018). The survey generally covers common science communication variables ranging from attitudes towards, beliefs in, and knowledge about science to a wide spectrum of media and non-media sources with which respondents could come into contact with science and research. Based on public telephone listings (90% landlines, 10% mobile), households were randomly selected, household members were chosen according to sex and age quotas and were interviewed using computer-assisted telephone interviews. A total of 1051 respondents participated (651, 200, 200 from the German-, French-, and Italian-speaking parts of the country, respectively). The final sample was weighted regarding cantons, size of living area, gender, age, education, occupation and household size.

Methods and measurements

Regarding *RQ*1, we ran a linear regression[1] to correlate people's interest in participating in CS with their sociodemographics and attitudes towards science. While this secondary analysis benefitted from nationally representative data, we were limited by only having one item available to assess interest in CS. The item for the dependent variable was 'I would like to participate in scientific research projects (once)',[2] with interviewers instructed to explain if necessary that participating in research did not mean being the object of analysis but active participation in data acquisition and/or data analysis. Answers could range from 1 = do not agree at all to 5 = agree strongly. Responses to this item were then modelled using two sets of commonly used explanatory variables.

We first used traditional *sociodemographic variables* (Table 1). They cover people's age, their gender (% female), education (% tertiary education), occupation status (% full-time employed), household situation (% living in households with children) and their proximity to science, which is a sum-index (0–4) representing whether people are scientists themselves (4 points), or whether they personally know a scientist, work in a science-related environment or have family members who (used to) study at a university (one point per affirmative answer). In addition, we included a global measure of people's political orientation (1 = left to 7 = right) and religiosity (1 = not at all religious … 5 = very religious) (Besley, 2018; Runge et al., 2018).

A second set of indicators covered attitudes towards science (Schäfer et al., 2018), which we measured regarding cognitive, affective and conative aspects (Table 1):

- To assess the *cognitive aspect*, we measured respondents' knowledge about science. Knowledge about science is often assessed via quiz statements focusing on STEM subjects in surveys, e.g. 'Electrons are smaller than atoms' (Kawamoto et al., 2013; Miller, 1983). As this quiz format has been criticized (e.g. Pardo & Calvo, 2002, 2004), however, we use it in adapted form. First, we included questions about arts and humanities, about textbook and applied scientific knowledge, and about the process of science (Schäfer et al., 2018). Second, we moved from the established dichotomous 'correct–false' answer format, which gives respondents a 50% random chance to answer correctly, to a format allowing respondents to indicate the level of certainty in their answers (Taddicken et al., 2018). Answers for the 11 items were combined in an index: correct answers gave respondents one point for the 'likely' and two points for the 'definitely' version. Incorrect or 'do not know' answers were assigned zero points. The index value is the arithmetical mean of points per question, ranging from 0 to 2. In addition to knowledge, we asked for respondents' *interest in science*, employing a question that was widely used in several surveys (Besley, 2013).
- The *affective aspect* of attitudes was measured by asking respondents for their general trust in science (Lee, Scheufele, & Lewenstein, 2005), as well as for their assessment of whether science plays an important role in their lives (Schäfer et al., 2018).
- We assessed the *conative aspect* – as the behavioural component of attitudes is often operationalized in studies of science communication (Bauer, 2016; Eurobarometer, 2005) – with a question asking whether respondents actively search for information about science (Wissenschaft im Dialog, 2015).

For *RQ*2, we ran latent class analyses – a model-based clustering technique (Chapman and Feit, 2015) – with the subset of the overall population that 'agreed' or 'strongly agreed' to the question of whether they would like to participate in scientific research projects ($N_{\text{subset}} = 381$). Employing all explanatory variables from our regression models, we determined optimal solutions from one up to eight clusters using the LatentGold 5.1 software (Vermunt and Magidson, 2016). We entered 5000 random sets of starting values into the algorithm to ensure valid and robust solutions (see Supplementary Appendix for full specifications). Bayesian information criterion (BIC) values, which assess solutions by balancing between a minimum of unexplained variation in the dependent variable and a low number of explanatory variables, favoured the five-cluster solution (see Supplementary Appendix). Since this solution also offered a clear interpretation of the five segments, we chose this solution. For presentation of results, we use the modal attribution of cases; that is, we assigned each respondent to her or his most probable segment. For more than 99.7% of

Table 1. Items used in our study.

Dimension	Items	*N*	*M*	*SD*
Interest in citizen science	I would like to participate in scientific research projects (once) (1 = do not agree at all − 5 = agree strongly)	1043	2.86	1.39
Attitudes towards science and research				
Cognitive	Scientific literacy (index: 0–2; no/incorrect answer = 0 pts., correct ‘likely’ – answer = 1 pt., correct ‘definitely’ – answer = 2pts.)	1051	1.23	0.36
	How interested are you in science and research? (1 = not at all interested − 5 = very interested)	1050	3.45	1.11
Affective	Science and research play an important role in my life (1 = do not agree at all − 5 = agree strongly)	1044	3.14	1.19
	How high is your trust in science in general? (1 = very low − 5 = very high)	1042	3.58	0.74
Conative	I specifically search for information about science and research (1 = do not agree at all − 5 = agree strongly)	1048	3.13	1.35
Sociodemographics	Gender (% female)	1051	50.8	–
	Age (years)	1051	46.3	17.90
	Education (% tertiary education)	1046	43.3	–
	Proximity to science (index: 0–4)	1049	1.59	1.26
	Household situation (% living in households with children)	1048	69.7	–
	Occupation status (% who work full-time)	1043	36.4	–
	Religiosity (1 = not at all religious − 5 = very religious)	1047	2.72	1.25
	Political orientation (1 = left − 7 = right)	998	3.64	1.28
Interest in scientific topics	How interested are you in … (1 = not at all interested − 5 = very interested) … Medicine	1050	3.82	1.05
	… Environment and energy	1051	3.92	0.93
	… Biology	1048	3.27	1.22
	… Space exploration	1048	2.57	1.63
	… Political science	1049	2.92	1.34
	… Psychology	1051	3.27	1.41
	… History	1050	2.98	1.49
Legacy media contact with science and research	How often do you come in contact with science and research via … (1 = never − 5 = very often) … Swiss Public Television (SRF)	1045	2.86	1.20
	… Other Television	1034	2.65	1.23
	… Swiss Public Radio (SRF Radio)	1040	2.36	1.29
	… Other radio	1036	1.64	1.00
	… Daily/weekly newspapers and magazines	1042	3.28	1.22
	… Science magazines	1032	1.95	1.28
	… Internet	1045	3.12	1.38
Online contact with science and research	… Online outlets of newspapers and magazines	1042	2.23	1.33
	… Online archives of television and radio channels	1039	1.90	1.14
	… Institutional websites (scientific, government, organizations)	1041	2.31	1.28
	… Facebook	1044	1.55	1.06
	… Blogs or message boards	1042	1.54	0.90
	… Wikipedia	1040	2.72	1.40
	… YouTube or similar video platforms	1043	2.22	1.29

Table 1. (Continued)

Dimension	Items	*N*	*M*	*SD*
Other contact with science and research	How often do you do one of the following … (1 = never … 5 = very often) … Visit museums and exhibitions covering science and research	1049	2.47	1.08
	… Visit zoos, aquariums or botanical gardens	1050	2.71	1.13
	… Attend events, talks, discussions concerning science and research	1050	2.09	1.09
	… Read nonfiction books on science and research	1051	2.51	1.28
	… Watch movies related to science and research in the cinema	1049	2.32	1.18
	… Talk about science and research with friends and acquaintances	1051	3.11	1.12

M: mean; *SD*: standard deviation.

respondents, the likelihood of belonging to one segment exceeded 50%. The overall hit rate – defined as the sample mean of all respondents' posterior probabilities (Gollwitzer, 2012) – reached 94%, meaning that survey respondents were, on average, 94% likely to belong to one specific segment.

For *RQ*3, we further detailed the description of the newly identified segments by adding variables about people's topical interests and the channels of information through which they come into contact with science and research. The latter included (1) legacy media, (2) online media and (3) other forms of contact with science and research like conversations with friends or visits to museums and zoos (Table 1).

4. Results

RQ*1: Who is willing to participate in CS?*

Among our 1051 respondents, 381 indicated that they are either interested or very interested to participate in scientific research projects. This suggests that more than a third (36.2%) of the Swiss population could be motivated to participate in CS (see Supplementary Appendix).

But who are these potential citizen scientists? Using linear regression including the explanatory factors outlined above (Table 2), we were able to explain 35.1% of people's willingness to participate in scientific research projects, that is, in CS projects – a relatively high number for linear regression models in communication science (Reinard, 2006). First, several sociodemographic variables explain this willingness: people who are younger, have a higher proximity to science, and live in households with children[3] are more likely to be interested in participation in scientific research. Notably, however, the results do *not* indicate that respondents' gender, education level, employment status, religiosity or political orientation are relevant explanatory factors.[4]

Second, several attitudinal variables influence the willingness to participate in CS: peoples' interest in science, their feeling that science plays an important role in their life and their proneness to seek information about science – that is, cognitive as well as affective and conative factors – show the strongest relations. Our analysis further suggests that neither respondents' scientific literacy nor their trust in science is a relevant predictor of their willingness to participate in CS.

Table 2. Regression model for people's willingness to participate in scientific research projects.

Explanatory variables	DV: 'I would like to participate in scientific research projects (once)'		
	Std. Betas	CI	*p*
(Intercept)	−0.02	−0.07 − 0.04	0.231
Age	−0.12	−0.18 –0.07	<**0.001*****
Female (1 = yes, 0 = no)	−0.01	−0.07 − 0.05	0.689
Tertiary education (1 = yes, 0 = no)	−0.00	−0.06 − 0.06	0.921
Household with Children (1 = yes, 0 = no)	0.09	0.04 − 0.15	**0.001****
Full-time work (1 = yes, 0 = no)	−0.00	−0.06 − 0.05	0.886
Political orientation (left:1–7: right)	0.02	−0.04 − 0.07	0.54
Religiosity (1–5)	−0.02	−0.07 − 0.03	0.487
Proximity to science (0–4)	0.07	0.01 − 0.13	**0.02***
Scientific literacy (0–2)	0.02	−0.04 − 0.07	0.567
Trust in science (1–5)	0.03	−0.03 − 0.09	0.313
Interest in science (1–5)	0.14	0.08 − 0.21	<**0.001*****
Personal life-relevance of science (1–5)	0.36	0.30 − 0.43	<**0.001*****
Science information seeking (1–5)	0.12	0.05 − 0.18	<**0.001*****
N =	952		
R^2/adjusted R^2	0.360/0.351		

CI: confidence interval.

RQ2: *Among Swiss citizens interested to participate in CS, which segments can be differentiated?*

Latent class analysis constructed five segments of respondents who are all interested in participating in CS (Table 3). The five segments differ clearly in their sociodemographic and science-related characteristics and can be compared with respondents who were not willing to participate in CS and were excluded from segmentation analysis – called 'non-CS' *(n = 670)* from here on.

The '*Free-Timers*' (*n* = 118) form the largest segment, representing 11.2% of the Swiss population and 31% of those who would be willing to participate in CS. On average, they are 55 years old. They are mostly women (54.5%), and, in stark contrast to all other groups, almost none of them (1%) work full-time. A closer look at their employment status reveals that this group mainly consists of people who are part-time employed (58.7%), retired (20.2%) or homemakers (13.1%). Similar to all other CS groups, 'Free-Timers' have significantly[5] more positive cognitive, affective, and conative attitudes towards and trust in science (means ranging around 3.5) than the rest of the population. Their scientific literacy and proximity to science, however, do not significantly differ from that of the 'non-CS' group. The remaining indicators like their education, political ideology, scientific literacy and proximity to science do not significantly differ from the rest of the population ('non-CS') either.

The '*Senior Sciencephiles*' (*n* = 89) are the second largest group, consisting of 8.5% of our representative sample and represent 23.4% of those who would be willing to participate in CS. We named them 'Sciencephiles' in reference to a group regularly described in science communication (Kawamoto et al., 2013; Schäfer et al., 2018:): a part of the population that shows highly positive attitudes towards science (ranging around 4.2) is predominantly male (83.3%) and tends to have

Table 3. Segment variable means for the five-cluster solution as well as for people not interested in participating in CS.

Segments (*N* = 1051)	Non-CS (63.75%)	Free-timers (11.23%)	Senior sciencephiles (8.47%)	Young sciencephiles (4.09%)	Intrigued adolescents (6.95%)	Fully employed parents (5.52%)
Age	48.15	55.38	54.50	25.57	17.94	45.62
Female (%)	54.54	82.74	16.72	34.59	42.55	17.00
Tertiary education (%)	39.29%	43.91	89.33	62.90	2.09	54.27
Household with children (%)	65.64%	58.69	79.72	75.59	93.87	88.42
Full-time work (%)	33.38%	0.95	77.37	33.28	22.02	100.00
Political orientation (left: 1–7: right)	3.66	3.70	3.61	3.31	3.37	3.91
Religiosity (1–5)	2.83	2.95	2.40	1.83	2.43	2.47
Proximity to science (0–4)	1.34	1.53	2.89	3.32	1.38	1.62
Scientific literacy (0–2)	0.77	0.81	1.05	0.89	0.72	0.87
Trust in science (1–5)	3.48	3.68	3.87	4.19	3.67	3.46
Interest in science (1–5)	3.17	3.70	4.42	4.70	3.63	3.43
Personal life-relevance of science (1–5)	2.76	3.75	4.12	4.45	3.51	3.40
Science information seeking (1–5)	2.78	3.41	4.24	4.28	3.56	3.37

CS: citizen science.

higher than average proximity to science (2.89), trust in science (3.87) and scientific literacy (1.05). We use the term 'senior' because this segment is 55 years on average and also because it has the largest share of people with tertiary education (89.3%). The 'Senior Sciencephiles' tend to live in households with children (79.7%) and are likely working full-time (77.4%). They do not differ from the rest of the population ('Non-CS') concerning their political orientation but are significantly less religious.

As their name indicates, the '*Young Sciencephiles*' (*n* = 43; 4.1% of population, 11.3% of those who are willing to participate in CS) are similar to their senior counterparts: they are mostly male (65.4%) and do not display any significant differences regarding their positive attitudes towards science (around 4.2), trust in science (4.19) and proximity to science (3.32). Only their scientific literacy (0.89) is significantly lower than the 'Senior's', while being significantly higher than that of all other groups. The striking difference is, of course, their young average age of 25.6 years. Generally, the 'Young Sciencephiles'' have the lowest levels of religiosity (1.83), most left-leaning political orientation (3.31), are more educated (62.9% tertiary) than the rest of the population ('Non-CS') and tend to have work arrangements that do not occupy them full-time (33.3% work full-time, the rest are still undergoing education or work part-time).

The '*Intrigued Adolescents*' (*n* = 73) stand for 7% of the Swiss population and for 19.2% of those who would be willing to participate in CS. As our youngest group was about 18 years old, this set of respondents did not yet have an opportunity to acquire tertiary education (2.1%) as 68% of them were still in school. These adolescents do not significantly differ from the 'Non-CS' population with regard to their proximity to science (1.38), trust in science (3.67) or scientific literacy (0.72). However, they have significantly more positive attitudes towards science (around 3.5),

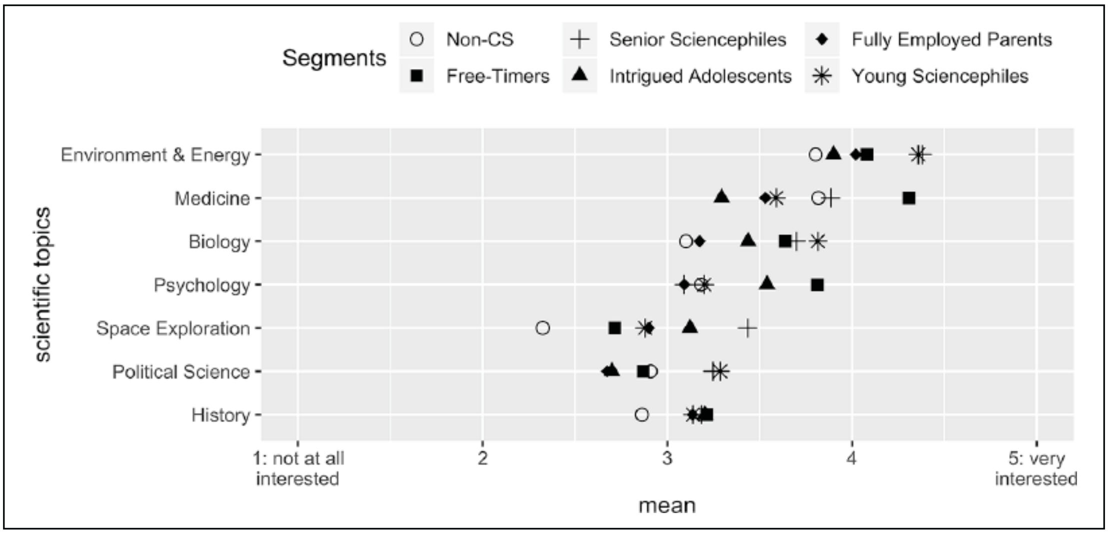


Figure 1. Interest in various scientific topics across population segments (descending means).

similar to the 'Free-Timers' but significantly lower than the two 'Sciencephiles'. While it might not be ideal to overemphasize political orientation for such young respondents, the 'Intrigued Adolescents' tend to have low levels of religiosity (2.47) and are the CS group with the best gender balance (42.6% women).

Representing 5.5% of the population and 15.2% of those willing to participate in CS, the '*Fully Employed Parents*' ($n = 58$) are a group with an average age of 45.8 years that predominantly consists of men (83%) living in households with (most likely their own) children (88.4%) and working full-time exclusively (100%). Their attitudes towards science match the ones of the 'Free-Timers' and the 'Intrigued Adolescents'. The same is true for their trust in science (3.46), scientific literacy (0.87) and proximity to science (1.62), which also are on the same level as the'non-CS' group.

RQ3: *What are the best ways to address the segments with regard to their topical interests and commonly used communication channels?*

The five segments of respondents willing to participate in CS do not only differ along the 13 variables used for clustering. They also differ in the specific fields of science they are interested in, and in the communication channels they regularly use to come in contact with science. These differences point to target-specific ways to address segments and improve recruitment success.

Figure 1 shows specific scientific topics that the five segments might be interested in. Overall, we see that environment and energy, and medicine are rated as the most interesting topics by almost all segments. The only exceptions are the 'Young Sciencephiles', who prefer biology to medicine, and the 'Intrigued Adolescents', who regard psychology as more interesting than medicine. Unsurprisingly, biology and psychology are also topics that all groups consider interesting (i.e. above 3.0 scale points). While it is not any segment's favourite, space exploration is the only topic in which the rest of the population ('Non-CS') significantly trails behind all five CS segments' interest.

The top section in Figure 2 depicts the main legacy media information sources that people have available in Switzerland. Overall, we see that the segments do not greatly differ from the 'non-CS' population. The Internet is the only source where all CS segments indicated significantly higher frequencies. Except for the 'Free-Timers', who prefer newspapers, the Internet is the most frequent source of the other four CS groups, followed by daily and weekly newspapers and magazines and

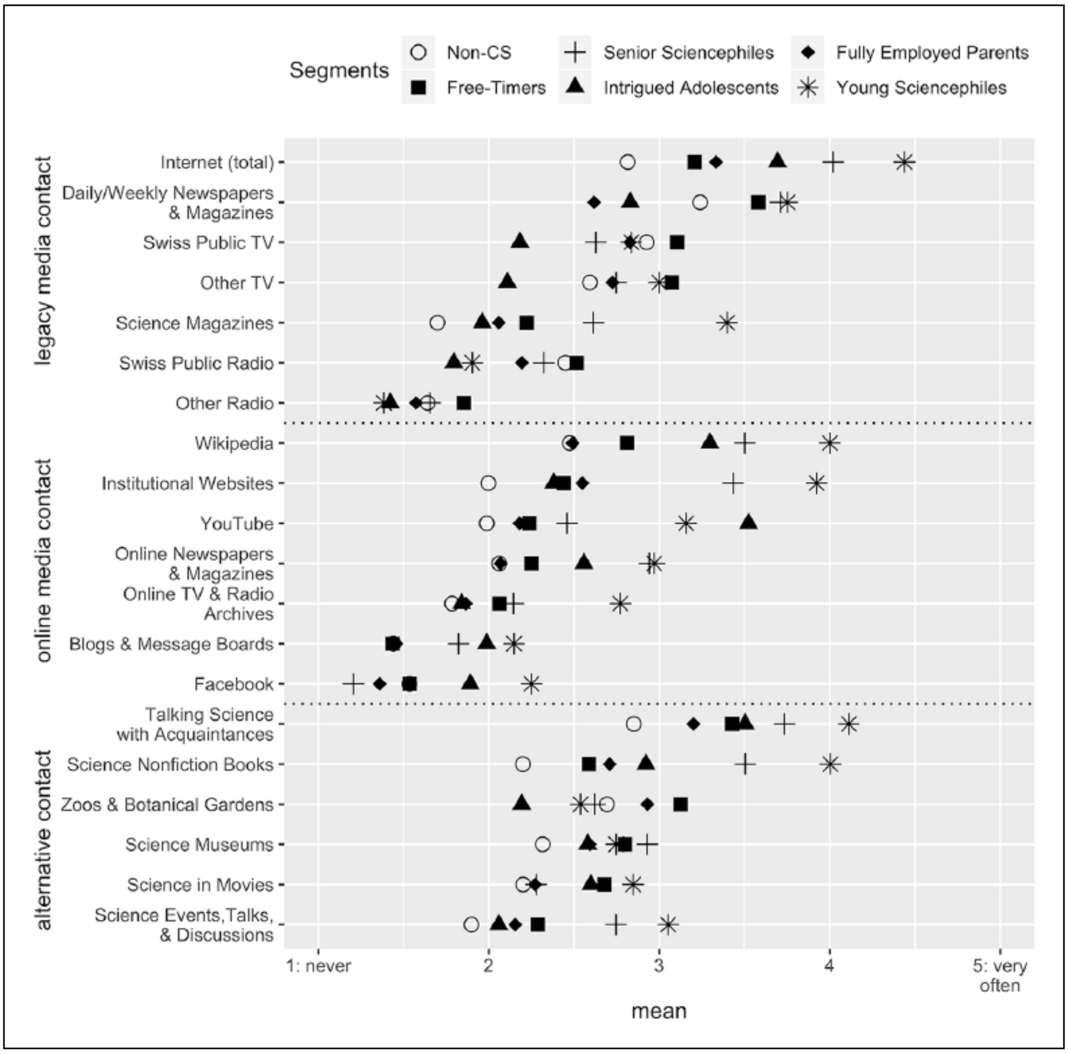


Figure 2. Frequency of legacy media, online media and alternative contact with science and research across population segments (descending means per category).

Swiss public television. Furthermore, science magazines are the source that is most likely to reach a specific group, as the 'Young Sciencephiles' read them significantly more often than any other group.

Segments show more pronounced differences across specific online sources, however (middle section in Figure 2). The 'Young Sciencephiles' and the 'Senior Sciencephiles' mostly frequent websites from official authorities and scientific institutions as well as Wikipedia entries, while the 'Intrigued Adolescents' regularly come across scientific content on YouTube and Wikipedia. The 'Free-Timers' and 'Fully Employed Parents' have online contact with science and research on a level comparable with the 'non-CS' group. The only source where they have higher means are institutional websites, something which applies to all CS segments.

A more likely way to reach 'Free Timers' and 'Fully Employed Parents' are alternative contact forms with science and research (bottom section in Figure 2). Group means suggest that these two groups are the most likely to go to zoos and botanical gardens – although only the 'Free-Timers' do so significantly more often than the rest of the population. Science-related books and talking about science with acquaintances are the two contact forms where all CS groups display significantly higher frequencies than the 'non-CS' group, both activities most likely done by the young and senior 'Sciencephiles'. To a lesser extent, science events, talks and discussions are places where people interested in participating in CS are more likely to be found than the rest of the population ('Non-CS'), with significantly higher values for the two 'Sciencephiles' and the 'Free-Timers'.

5. Discussion and conclusion

The rise of CS is one of many phenomena that can be attributed to science and society moving closer together, a process catalyzed by digital media (Dickel and Franzen, 2016). CS projects offer academic output for scientists as well as genuine engagement with science for a potentially broad spectrum of participants. Accordingly, scholars have linked CS with the ideal of democratizing science through public participation in knowledge production (Hecker et al., 2018). While many projects are able to recruit large numbers of participants, they only seem to reach a certain part of the population that is mostly male, highly educated and scientifically literate, and already has highly favourable attitudes towards science (Curtis, 2018; Pandya and Dibner, 2018). Current CS, it seems, does not yet come close to engaging a broad and diverse public. However, it remains unclear whether future CS projects have the potential to reach a wider range of participants, what these participants look like and how they are likely to be reached and convinced to participate.

Our study looked beyond participants who had already signed up for CS projects. Based on a national representative survey, it measured the Swiss' interest in participating in scientific research projects. The results show that approximately one-third of the population (36.2%) is interested in participating in CS. This is a promising percentage compared to the 19.5% of the Swiss population that engaged in institutionalized voluntary work[6] in 2016 (Federal Statistical Office, 2019).

Linear regression analysis (Table 2) confirmed that people interested in participation have more positive attitudes towards science (cognitive, affective and conative) – and tend to have a social environment that is related to scientific research. This suggests that potential citizen scientists are very likely to have a favourable outlook on science and scientific research to begin with, and that the CS is mostly found in a science-interested subset of the population.

Further results, however, go against conclusions drawn from participant samples: neither people's gender, education nor scientific literacy are relevant predictors for people's interest in participating in CS. Moreover, our regression model shows that having children in one's household has a significant relation with people's interest in CS. All of these findings make clear that CS projects do have the potential to recruit a more diverse set of participants that goes beyond highly educated men. As a novel insight, our data suggest that family households might be a worthwhile target of recruitment in general. Future studies might try to dive deeper and find out whether people who live in households with children would be interested in 'Family Citizen Science' or whether they are more interested in CS as an activity to 'take a break' from family life.

Beyond the general characteristics of potential citizen scientists, we identified five population segments (Table 3) among people who declared an interest in participating in scientific research projects (N=381). As predicted by the regression analysis, all segments are characterized by positive to very positive attitudes towards science. On one hand, we find the 'Senior and Young Sciencephiles', who are reminiscent of typical CS participants. On the other hand, we reconstructed three segments that have been underrepresented in CS projects so far: the 'Free-Timers' mostly consist of women and have more leisure time at their disposal; the 'Intrigued Adolescents' are the youngest group, are not highly educated (yet) and have a proximity to science similarly low as the rest of the Swiss population; finally, the 'Fully Employed Parents' work in full-time jobs, and are highly likely to have children at home.

Since only two of five segments resemble participants in current CS projects, it is important to analyse how these other groups can be reached and addressed. Our results show that potential citizen scientists are most interest medicine and environmental and energy issues, but also that the ‘Free-Timers’ would be more interested in medicine-related projects while the four other segments are a better fit for environment-related issues. We also see that topics like history and political science are only slightly more popular among CS segments than across the rest of the population (i.e. the ‘non-CS’ group) and might make for projects that find it more difficult to acquire participants.

Looking at journalistic news media and online sources, we see that it could be challenging to reach the three underrepresented CS segments in the first place. The ‘Young and Senior Sciencephiles’ are most frequently exposed to science on almost all the channels; the Internet, more specifically institutional websites and Wikipedia, being the most pronounced source. Project organizers who want to reach other potential participants might have to take advantage of other communication forms. For example, ‘Intrigued Adolescents’ often encounter science on YouTube, which offers the possibilities of video or targeted ad campaigns. ‘Free Timers’ and ‘Fully Employed Parents’, on the other hand, are the two groups significantly most likely to go to, and therefore be reached in, zoos and botanical gardens (mean frequency around 3). A hidden feature of all groups is that they frequently talk about science with their friends and family, increasing the chance of organic word of mouth campaigning.

Implications and limitations

Our study implies that CS projects have a significantly more diverse pool of potential participants than they were previously able to motivate. This finding is limited by the fact that our item asked about ‘participating in scientific research’ rather than naming ‘citizen science’ directly. We chose this wording because the Swiss public would not have been familiar with the term ‘citizen science’. The question remains whether the respondents were thinking about something similar to CS or whether they have other forms of participation concretely in mind at all – this cannot be clarified with our data. Our findings can be somewhat corroborated by the German Science Barometer, however, which clearly asked about CS, used the term itself and also found that 30% would like to participate, with a distribution similar to the Swiss one (Wissenschaft im Dialog, 2014).

We also would like to point out that our unique perspective only sheds light on one specific step of potential participation in CS projects – peoples’ initial interest. While behavioural intentions have proven to be strong predictors of actual behaviour (Ajzen, 2011), there will still be a large number of ‘inclined abstainers’ who say they want to participate but never do (Sniehotta et al., 2014, p. 2). This is not surprising as the chain of actions from interest to participate to prolonged participation is long and complex (Weitkamp, 2016). For example, we do not know which kind of project our potential citizen scientists would like to be a part of, whether they have participated in CS before or what kind of tasks they would be willing to do (Shirk et al., 2012). In addition, once people have started to participate, their motivations become diverse and key factors in maintaining participation and affecting outcomes like knowledge and attitudes (Jennett et al., 2016). Future studies that can work with representative data sets should aim to include more variables than just one-item measures of people’s basic interest in CS and include specific questions about prior participation and interest in project types, tasks and topics.

The large variability in segment characteristics highlights that general interpretations of the regression model are helpful for a relative description of factors but do not tell us much about the actual characteristics of potential citizen scientists. For example, proximity to science was a significantly positive predictor but there are groups like the ‘Free-Timers’ and ‘Young Adolescents’ with an average proximity to science. The small but significant correlation of people’s age does also not directly translate to our segments who display a broad range of mean ages. We think that regression models are worthwhile as future research can parse out whether there are more universal predictors for people’s willingness to participate in CS. If project organizers have access to their country-specific data though, it will be more effective to focus on tailored segmentation analyses.

Future CS scholarship could benefit from research on volunteering: It would be interesting to assess CS participation rates and compare them with voluntary engagement rates in sectors like sports, culture and education (Simonson et al., 2017). In addition, the catalogue of motives developed in research on (maintained) volunteering could be incorporated in CS research (Müller et al., 2017). For example, the role of monetary incentives has not been empirically considered in CS research yet (Hecker et al., 2018).

When it comes to the potential of CS to enable public and open knowledge production, it is not enough to know which people to reach through which communication channels for which project type and how to motivate them to participate. While this was outside of the scope of our study, it would be worthwhile to investigate the gap we discovered between groups interested in CS and groups actually reported in CS projects. Concepts like cultural capital and threshold fear might offer an interesting perspective for such investigations as they describe how certain groups like women and less educated people might still ultimately refrain from actually participating in research projects due to cultural forces (Curtis, 2018). Only if these aspects receive more attention, the full potential of CS can be unlocked.

Acknowledgements

We would like to thank the reviewers for their valuable feedback on this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by Gebert Rüf Stiftung [grant number GRS-025/15]; and Stiftung Mercator Schweiz [grant number 2014-0607].

Supplemental material

Supplemental material for this article is available online at https://journals.sagepub.com/home/pus.

Notes

1. We checked model assumptions – no assumptions were violated – and ran the model in R using the ‘sjPlot’ package (Lüdecke (2018).
2. The original wording in German is, ‘Ich würde gern einmal in wissenschafltichen Projekten mitforschen’. The ‘once’ in the English translation should be understood as ‘once or more’.
3. We would like to emphasize that living in a household with children can also mean that the respondents themselves live with their parents. We reran the analysis for respondents older than 25 and discovered the same main effects (see Supplementary Appendix).
4. Political orientation was the variable that elicited by far the most amount of missing values. Seeing the insignificance of this predictor, we reran the analysis without people’s political orientation and discovered the same main effects.
5. We have run pairwise (Holm correction) *t*-tests regarding group means for each variable that was used to describe segments from here on out. We use $p < 0.05$ significances as a means to identify and describe the most striking segment differences. We abstained from depicting this information in tables and figures

because they would become hard to read. However, all pairwise comparisons for each variable can be found in the Supplementary Appendix.
6. Defined as voluntary work that goes beyond helping friends and family, for example, political engagement or helping a local sports club.

ORCID iDs

Tobias Füchslin https://orcid.org/0000-0002-2395-9674
Mike S. Schäfer https://orcid.org/0000-0002-0847-7503
Julia Metag https://orcid.org/0000-0003-4328-6419

References

Ajzen I (2011) The theory of planned behaviour: Reactions and reflections. *Psychology & Health* 26(9): 1113–1127.
Alender B (2016) Understanding volunteer motivations to participate in citizen science projects: A deeper look at water quality monitoring. *Journal of Science Communication* 15(3). DOI: 10.22323/2.15030204
Bauer MW (2016) *The Culture of Science Indicators*. London: The London School of Economics and Political Science.
Besley JC (2013) The state of public opinion research on attitudes and understanding of science and technology. *Bulletin of Science, Technology & Society* 33(1–2): 12–20.
Besley JC (2018) Audiences for science communication in the United States. *Environmental Communication* 12: 1005–1022.
Bonney R, Ballard H, Jordan R, McCallie E, Phillips T, Shirk J, et al. (2009) *Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education*. Washington, DC: Center for Advancement of Informal Science Education. Available at: http://files.eric.ed.gov/fulltext/ED519688.pdf
Bonney R, Phillips TB, Ballard HL and Enck JW. (2016) Can citizen science enhance public understanding of science? *Public Understanding of Science* 25(1): 2–16.
Chapman C and Feit EM (2015) *R for Marketing Research and Analytics*. Cham: Springer.
Curtis V (2018) *Online Citizen Science and the Widening of Academia: Distributed Engagement with Research and Knowledge Production*. Cham: Springer.
Dean AJ, Church EK, Loder J, Fielding KS and Wilson KA (2018) How do marine and coastal citizen science experiences foster environmental engagement? *Journal of Environmental Management* 213: 409–416.
Dickel S and Franzen M (2016) The 'problem of extension' revisited: New modes of digital participation in science. *Journal of Science Communication* 15(1). DOI: 10.22323/2.15010206.
Eurobarometer S (2005) Europeans, science and technology. Available at: http://ec.europa.eu/commfrontoffice/publicopinion/archives/ebs/ebs_224_report_en.pdf
Fähnrich B, Janssen Danyi C and Nothhaft H (2015) The German plagiarism crisis: Defending and explaining the workings of scholarship on the front stage. *Journal of Communication Management* 19(1): 20–38.
Federal Statistical Office (2019) Freiwilligenarbeit [voluntary work]: Beteiligung der Bevölkerung in % [public participation in %]. Available at: https://www.bfs.admin.ch/bfs/de/home/statistiken/arbeit-erwerb/unbezahlte-arbeit/freiwilligenarbeit.html
Gibbons M, Limoges C, Nowotny H, Schwartzman S, Scott P and Trow M (1994) *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*. London: SAGE.
Gollwitzer M (2012) Latent-class-analysis. In: Moosbrugger H and Kelava A (eds) *Testtheorie Und Fragebogenkonstruktion* [test-theory and questionnaire construction]. Berlin; Heidelberg: Springer, pp. 295–323.
Haklay M (2018) Participatory citizen science. In: Hecker S, Haklay M, Bowser A, Makuch Z, Vogel J and Bonn A (eds) *Citizen Science: Innovation in Open Science, Society and Policy*. London: UCL Press, pp. 52–62.
Hecker S, Haklay M, Bowser A, Makuch Z, Vogel J and Bonn A (eds) (2018) *Citizen Science: Innovation in Open Science, Society and Policy*. London: UCL Press.

Irwin A (1995) *Citizen Science: A Study of People, Expertise and Sustainable Development*. London: Routledge.
Jennett C, Kloetzer L, Schneider D, Iacovides I, Cox A, Gold M, et al. (2016) Motivations, learning and creativity in online citizen science. *Journal of Science Communication* 15(3). DOI: 10.22323/2.15030205.
Kawamoto S, Nakayama M and Saijo M (2013) A survey of scientific literacy to provide a foundation for designing science communication in Japan. *Public Understanding of Science* 22(6): 674–690.
Kullenberg C and Kasperowski D (2016) What is citizen science? A scientometric meta-analysis. *PLoS ONE* 11(1): e0147152.
Land-Zandstra AM, Devilee JLA, Snik F, Buurmeijer F and van den Broek JM (2016) Citizen science on a smartphone: Participants' motivations and learning. *Public Understanding of Science* 25(1): 45–60.
Lee C-J, Scheufele DA and Lewenstein BV (2005) Public attitudes toward emerging technologies. *Science Communication* 27(2): 240–267.
Lewenstein B (2016) Can we understand citizen science? *Journal of Science Communication* 15(1). DOI: 10.22323/2.15010501.
Lüdecke D (2018) sjPlot: Data visualization for statistics in social science. Available at: https://CRAN.R-project.org/package=sjPlot
Lynch LI, Dauer JM, Babchuk WA, Heng-Moss T and Golick D (2018) In their own words: The significance of participant perceptions in assessing entomology citizen science learning outcomes using a mixed methods approach. *Insects* 9(1): 16. DOI: 10.3390/insects9010016.
Martin VY (2017) Citizen science as a means for increasing public engagement in science: Presumption or possibility? *Science Communication* 39(2): 142–168.
Miller JD (1983) Scientific literacy: A conceptual and empirical review. *Daedalus* 112(2): 29–48. Available at: http://www.jstor.org/stable/20024852
Miller-Rushing A, Primack R and Bonney R (2012) The history of public participation in ecological research. *Frontiers in Ecology and the Environment* 10(6): 285–290.
Müller D, Hameister N and Lux K (2017) Anstoß und Motive für das freiwillige Engagement [initiation and motives for voluntary engagement]. In: Simonson J, Vogel C and Tesch-Römer C (eds) *Freiwilliges Engagement in Deutschland [Voluntary Engagement in Germany]*. Wiesbaden: Springer; Fachmedien Wiesbaden, pp. 413–435.
Nature (2015) Rise of the citizen scientist. *Nature* 524(7565): 265.
Nowotny H, Scott P and Gibbons M (2001) *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty*. Cambridge, Ma: Polity Press.
Pandya R and Dibner KA (2018) *Learning Through Citizen Science: Enhancing Opportunities by Design*. Washington, DC: National Academies Press.
Pardo R and Calvo F (2002) Attitudes toward science among the European public: A methodological analysis. *Public Understanding of Science* 11(2): 155–195.
Pardo R and Calvo F (2004) The cognitive dimension of public perceptions of science: Methodological issues. *Public Understanding of Science* 13(3): 203–227.
Penner LA (2002) Dispositional and organizational influences on sustained volunteerism: An interactionist perspective. *Journal of Social Issues* 58(3): 447–467.
Reinard JC (2006) *Communication Research Statistics*. Thousand Oaks, CA: SAGE.
Runge KK, Brossard D and Xenos MA (2018) Protective progressives to distrustful traditionalists: A post hoc segmentation method for science communication. *Environmental Communication* 12(8): 1023–1045.
Schäfer MS, Füchslin T, Metag J, Kristiansen S and Rauchfleisch A (2018) The different audiences of science communication: A segmentation analysis of the Swiss population's perceptions of science and their information and media use patterns. *Public Understanding of Science* 27(7): 836–856.
Schäfer MS, Metag J, Feustle J and Herzog L (2016) Selling science 2.0: What scientific projects receive crowd funding online? *Public Understanding of Science* 27(5): 496–514.
Science et Cité (2015) Citizen science in der Schweiz: Situationsanalyse und Zukunftsperspektiven [Citizen science in Switzerland: situation analysis and future perspectives]. Available at: https://www.science-et-cite.ch/docs/projekte/150130_CitizenScienceSchweiz_VersandNetzwerk.pdf
SciStarter (2018) Project finder. Available at: https://scistarter.com/finder

Shirk JL, Ballard HL, Wilderman CC, Phillips T, Wiggins A, Jordan R, et al. (2012) Public participation in scientific research: A framework for deliberate design. *Ecology and Society* 17(2): 29. DOI: 10.5751/ES-04705-170229.

Simonson J, Ziegelmann JP, Vogel C and Tesch-Römer C. (2017) Zentrale ergebnisse des Deutschen Freiwilligensurveys 2014 [key findings of the German voluntary engagement survey 2014]. In: Simonson J, Vogel C and Tesch-Römer C (eds) *Freiwilliges Engagement in Deutschland* [Voluntary Engagement in Germany]. Wiesbaden: Springer Fachmedien Wiesbaden, pp. 21–27.

Sniehotta FF, Presseau J and Araújo-Soares V (2014) Time to retire the theory of planned behaviour. *Health Psychology Review* 8(1): 1–7.

Taddicken M, Reif A and Hoppe I (2018) What do people know about climate change – And how confident are they? On measurements and analyses of science related knowledge. *Journal of Science Communication* 17(3). DOI: 10.22323/2.17030201.

Vermunt JK and Magidson J (2016) Technical guide for Latent GOLD 5.*1: Basic, advanced, and syntax*. Available at: https://www.statisticalinnovations.com/wp-content/uploads/LGtecnical.pdf

Weingart P (2001) *Die Stunde Der Wahrheit? [The Moment Oftruth?]: Zum Verhältnis Der Wissenschaft Zu Politik, Wirtschaft Und Medien in Der Wissensgesellschaft [On Science's Relationship with Politics, Economics, and the Media in the Knowledge Society]* (1. Aufl.). Weilerswist: Velbrück Wiss. Available at: http://hsozkult.geschichte.hu-berlin.de/rezensionen/type=rezbuecher&id=768

Weitkamp E (2016) From planning to motivations: Citizen science comes to life. *Journal of Science Communication* 15(3). DOI: 10.22323/2.15030501.

West S and Pateman R (2016) Recruiting and retaining participants in citizen science: What can be learned from the volunteering literature? *Citizen Science: Theory and Practice* 1(2): 197.

Wissenschaft im Dialog (2014) Wissenschaftsbarometer 2014 [Science Barometer 2014]. Available at: https://www.wissenschaft-im-dialog.de/projekte/wissenschaftsbarometer/wissenschaftsbarometer-2014/

Wissenschaft im Dialog (2015) Wissenschaftsbarometer 2015 [Science Barometer 2015]. Available at: http://www.wissenschaft-im-dialog.de/projekte/wissenschaftsbarometer/

Zavestoski S, Shulman S and Schlosberg D (2016) Democracy and the environment on the internet. *Science, Technology, & Human Values* 31(4): 383–408.

Author biographies

Tobias Füchslin MA is a research and teaching associate at the division for science communication at the Department of Communication and Media Research (IKMZ), University of Zürich. His research focuses on attitudes towards science and research, scientific literacy, and citizen science.

Mike S. Schäfer is professor for science communication at the University of Zurich's Department of Communication and Media Research (IKMZ) and Director of the university's Center for Higher Education and Science Studies (CHESS). His research focuses on science communication and climate change communication, particularly online.

Julia Metag is professor for communication science at the University of Fribourg's Department of Communication and Media Research (DCM), Switzerland. Her research focuses on political communication, science communication, and media effects.

7.4 Metag et al. (2015)

Global warming's five Germanys: A typology of Germans' views on climate change and patterns of media use and information.

Metag, J., Füchslin, T., & Schäfer, M. S.

This article was originally published in:

Metag, J., Füchslin, T., & Schäfer, M. S. (2015). Global warming's five Germanys: A typology of Germans' views on climate change and patterns of media use and information. *Public Understanding of Science (Bristol, England)*, *26*(4), 434–451. https://doi.org/10.1177/0963662515592558

Article

P | U | S

Public Understanding of Science
2017, Vol. 26(4) 434–451

DOI: 10.1177/0963662515592558
journals.sagepub.com/home/pus
SAGE

Global warming's five Germanys: A typology of Germans' views on climate change and patterns of media use and information

Julia Metag, Tobias Füchslin and Mike S. Schäfer
University of Zurich, Switzerland

Abstract

People's attitudes toward climate change differ, and these differences may correspond to distinct patterns of media use and information seeking. However, studies extending analyses of attitude types and their specific media diets to countries beyond the United States are lacking. We use a secondary analysis of survey data from Germany to identify attitudes toward climate change among the German public and specify those segments of the population based on their media use and information seeking. Similar to the Global Warming's Six Americas study, we find distinct attitudes (Global Warming's Five Germanys) that differ in climate change–related perceptions as well as in media use and communicative behavior. These findings can help tailor communication campaigns regarding climate change to specific audiences.

Keywords

attitudes, audience segmentation, climate change, Germany, information, mass media, survey

1. Introduction

Climate change is one of the "defining issues of our age," according to United Nations (UN) General Secretary Ban Ki Moon (UN News Centre, 2014) and poses major political and societal challenges. Accordingly, the issue has a firm place on the public agenda in countries around the world (Schmidt et al., 2013), and many people hold strong views about these issues (European Commission, 2014; Nisbet and Myers, 2007). These public perceptions are important. They shape how individuals react to climate change and, ultimately, influence political decision-making since the implementation of mitigation and adaptation policies such as carbon taxes or subsidies for renewable energies relies on public legitimation.

Corresponding author:
Julia Metag, IPMZ—Institute of Mass Communication and Media Research, University of Zurich, Andreasstrasse 15, CH-8050 Zurich, Switzerland.
Email: j.metag@ipmz.uzh.ch

The views people hold about climate change are (also) shaped by communication. Since climate change is an unobtrusive issue, that is, abstract, complex, and not directly perceivable (e.g. Moser, 2010), people's views are often based on information provided by the news media or interpersonal communication (e.g. Arlt et al., 2011; Leiserowitz et al., 2015; Schäfer, 2012).

Therefore, many studies have analyzed how and to what extent news media and interpersonal communication influence people's views on climate change (for overviews, see Schäfer, 2015; Taddicken, 2013). Researchers have shown that communication can affect knowledge about climate change (Taddicken, 2013; Zhao, 2009) as well as awareness (Arlt et al., 2011; Sampei and Aoyagi-Usui, 2009; Taddicken, 2013), and in some cases, even behavioral intentions or action (Arlt et al., 2011; Cabecinhas et al., 2008).

These studies use multivariate statistics to tease out differences among respondents' knowledge, attitudes, or behaviors along demographic, psychological, or media use variables. The studies do not, however, account for the fact that the public may be segmented regarding climate change, that distinct attitude types may be distinguishable, and that the media use and communication patterns of these types may differ.

The best-known works demonstrating such segmentations are the Global Warming's Six Americas study by Anthony Leiserowitz et al. (2009, 2013a). They show, among other things, that US citizens' views on climate change differ strongly, and that these differences are accompanied by variations in the individuals' issue-specific media use and information seeking. People who doubt the existence of climate change rely on their friends and families for information while people who are "alarmed" about the issue use all mass media heavily (Leiserowitz et al., 2009: 28). Acknowledging and reconstructing such segmentation is not only relevant for the scientific community but is also crucial since communication campaigns can be designed to specifically address particular segments of the population (Hefner, 2013).

However, although the Global Warming's Six Americas study was recently extended to India (Leiserowitz et al., 2013b) and Australia (Morrison et al., 2013; Sherley et al., 2014), it is still unclear whether similar segments exist in other countries, to what extent the segments mirror Leiserowitz et al.'s (2009) typologies, and whether they correspond with specific patterns of information and media use in other countries.

This study aims to remedy these shortcomings. It uses data from a survey on Germans' views about climate change and presents a secondary analysis of this data in which most of the analytical dimensions relevant in the literature can be operationalized. We analyze whether the German population can be grouped into typologies similar to the typologies shown in the United States and India and whether corresponding differences in media and communication patterns are discernible. Germany is an interesting case for this analysis since the German context differs from the US context: the level of climate change skepticism is much lower than in the United States (Engels et al., 2013), the existence of climate change has been accepted more widely, and relatively broad consensus exists that political measures are necessary (Peters and Heinrichs, 2008).

2. Conceptual framework

Existing typologies and their usefulness

Typologies aim to condense different characteristics of their analytical objects in order to elucidate latent patterns. In doing so, typologies achieve something linear statistical analysis such as regression analysis does not: they allow researchers to identify homogeneous groups of people across different characteristics.

When it comes to attitudes toward climate change, the leading study is the Global Warming's Six Americas (Leiserowitz et al., 2013a, 2014). Based on surveys of the US population, the study identified six segments among respondents regarding climate change: the Alarmed, who are most engaged about global warming; the Concerned, who are convinced that global warming exists but are less involved; the Cautious, who are less certain and do not view global warming as a personal threat; the Disengaged, who have not put much thought into the issue of climate change at all; the Doubtful, who are split between people who believe that climate change exists but that natural changes are responsible and those who do not believe in it; and the Dismissive, who are engaged because they strongly believe that global warming is not happening (Leiserowitz et al., 2009: 3–4). In October 2014, the Concerned (31%) and the Cautious (23%) formed the largest part of the US population. The Disengaged constituted the smallest group, 7% of the population (Leiserowitz et al., 2014). Apart from distinguishing these "Six Americas," the study also showed how these groups differ in media use and information seeking. For example, the Alarmed are higher than average media users while the Dismissive mainly rely on their friends and families for information about climate change (Leiserowitz et al., 2009).

Thus far, the Six Americas study is the only one presenting such a typology for climate change and supplementing it with media use and information-seeking patterns. When the project was extended to India and to Australia—revealing that both populations could be segmented into Global Warming's Six Indias (Leiserowitz et al., 2013b) and Six Australias, respectively (Morrison et al., 2013)—neither study included media use or information seeking.

Similar studies exist for other related issues such as environmental or energy topics. Among these studies, however, Hefner's (2013) study is the only one that included media use and information seeking. She presents six types into which the German public can be grouped regarding their environmental attitudes and behavior, ranging from people who are highly concerned but do not exhibit environmentally friendly behavior to people who are not concerned at all. Using cluster analysis, she shows that these types also differ in communicative behavior and information gathering. For example, environmentally concerned people use quality newspapers more often, while the less environmentally concerned rely mostly on television.

Many other studies have proposed attitude-based typologies for countries other than the United States or Germany focused on environmental or energy questions. None, however, include media or communication variables. Sütterlin et al. (2011) analyze Swiss views on energy consumption. Similar to Leiserowitz et al. (2009) and Hefner (2013), the researchers show that the Swiss public can be segmented into six types based on energy-related behavioral characteristics, such as the idealistic type who performs the most energy-saving efforts or the convenience-oriented indifferent energy consumers who are ignorant about the increase in energy consumption and are least likely to change their behavior (Sütterlin et al., 2011). Another study distinguished three types of people in Portugal regarding recycling: One is positive about it, and two are reluctant or indifferent (Vicente and Reis, 2007).

In sum, these studies demonstrate that the population of different countries can be divided into distinct attitude types toward environmental and energy issues. This seems to apply to climate change as well, as the US, Australian, and Indian studies show. In addition, there is some evidence that these typologies correspond with different uses of media and other sources of information, that is, that the information-seeking patterns of people who have different attitudes differ systematically. However, whether such a typology for the case of climate change can be developed for countries other than the United States, Australia, and India, and whether it goes hand in hand with specific patterns of information and media use, remains to be shown.

Therefore, we pose the following research questions:

RQ1. Which segments of the German population can be distinguished regarding their attitudes toward climate change?

RQ2. Do the media and communication patterns of these segments differ?

Relevant dimensions for devising a typology of the German population

First, we create a typology of the German public based on climate change–related variables. In the second step, we characterize these types in terms of their communication patterns. In doing so, we rely on analytical dimensions used in previous studies on attitudes toward climate change and integrate studies that deal with environmental and energy questions. These dimensions include the cognitive, affective, and conative aspects of attitudes (Ajzen, 1989):

- *Concern about climate change*. A core dimension in people's attitudes toward climate change is their concern. This dimension includes cognitive components such as the perception of climate change as a problem as well as affective components such as the perceived threat from climate change impact such as natural disasters (Arlt et al., 2011; Leiserowitz et al., 2009).
- *Beliefs and issue involvement*. Regarding attitudes toward climate change, it is also crucial to what extent someone believes that climate change is actually occurring (Engels et al., 2013; Leiserowitz et al., 2009). This can comprise a person's certainty or doubt (Leiserowitz et al., 2014), beliefs about climate science (McCright and Dunlap, 2011), and whether global warming poses a personal threat (Leiserowitz et al., 2009).
- *Knowledge about climate change*. Another dimension that captures the cognitive component of attitudes toward climate change is someone's knowledge of climate change. Here, people's factual knowledge can be distinguished from self-assessments of own knowledge (Taddicken, 2013). Factual knowledge is usually assessed with quiz questions about the causes and consequences of climate change (Cabecinhas et al., 2008; Taddicken, 2013), while self-assessments inquire whether people feel well informed about the issue (Leiserowitz et al., 2009).
- *Climate change–related behavior*. The behavioral component of attitudes can be measured as behavioral intentions or actual behavior (Leiserowitz et al., 2009). Arlt et al. (2011) conceptualize climate change–related behavioral intentions as the intentions of making investments to protect the environment, of changing one's lifestyle, and of being politically active in promoting climate protection. Taddicken (2013) differentiates between the willingness to take responsibility and the willingness to act related to climate change. Energy conservation actions are often described as actual behavior closely related to climate change (Leiserowitz et al., 2009, 2014).
- *Policy preferences*. The Global Warming's Six Americas study also focuses on the extent to which people support climate policies such as regulating CO_2 emissions (Leiserowitz et al., 2009). The researchers assume that this attitudinal dimension is related to general beliefs about global warming.

Second, overarching values, such as attitudes toward the environment, as well as sociodemographics, are important for attitudes toward climate change (Taddicken, 2013):

- *General environmental awareness*. People who are aware of environmental problems tend to perceive climate change as a problem as well (Taddicken and Neverla, 2011). Awareness of environmental problems can be differentiated in self-oriented concern about environmental problems affecting one's own life and more general concerns (Hefner, 2013). Environmental awareness can also be understood as having affective, cognitive, and conative aspects (Diekmann and Preisendörfer, 2003).

- *Values*. Value orientations also influence climate change–related attitudes (Arlt et al., 2011; Engels et al., 2013). This includes basic values of freedom, equality, security, as well as altruism and hedonism (Arlt et al., 2011).
- *Subjective norms*. As studies on environmental awareness have shown, subjective norms—perceived norms emerging from the behavior of people who are important to an individual—can influence attitudes (Bamberg and Möser, 2007). The same effect of subjective norms should also be discernable when climate change–related attitudes are concerned.
- *Socio-demographics*. Variables such as age, education, income, sex, or household size are also relevant for one's attitudes toward climate change (Leiserowitz et al., 2009; Taddicken, 2013) as well as toward environmental and energy issues (Hefner, 2013; Sütterlin et al., 2011).

We will use these dimensions to analyze if the German public is segmented regarding their attitudes toward climate change. In the second step, we scrutinize whether these segments differ in how they use mass media and interpersonal communication for information about climate change. Therefore, variables that capture mass media use and information seeking are the third group of factors considered in our analysis:

- *Mass media use*. As studies have demonstrated, the frequency of media use as well as the chosen media channel—newspapers, magazines, radio, or TV—can influence attitudes toward global warming (Arlt et al., 2011; Taddicken, 2013).
- *Perceived quality of media outlets*. Related to the use of mass media is how individuals perceive the quality of information they receive about climate change from the different media outlets. The higher the perceived quality, the more persuasive the pieces of information (O'Keefe, 1990).
- *Interpersonal communication*. Information about climate change can also be received through interpersonal contacts (Leiserowitz et al., 2015). The more people talk to others about climate change, the more information people get about climate change that can influence their own attitudes.

3. Data and method

Data

Our data stem from a nationwide representative telephone (computer-assisted telephone interviewing (CATI)) survey of 3000 Germans aged 18 years and older, funded by the University of Hamburg's Federal Research Cluster of Excellence (CliSAP) and conducted from April to June 2011.[1] As Figure 1 shows, the survey was conducted during a period of moderate societal attention for climate change in Germany. Media attention—as measured by keyword searches in the five most important German daily newspapers and two weeklies—was at a medium level after a strong peak around the 15th Conference of the Parties (COP 15) in Copenhagen in 2009 (Schäfer et al., 2014). Google trends data, measuring Google search requests for these climate change-related keywords from 2004 to 2011, largely mirror the media attention. The Eurobarometer surveys on attitudes toward climate change indicate that most Germans saw climate change as a serious problem at the time but that these worries had decreased slightly in 2011. Although these data helpfully contextualize the situation in Germany regarding climate change, the audience segments we focus

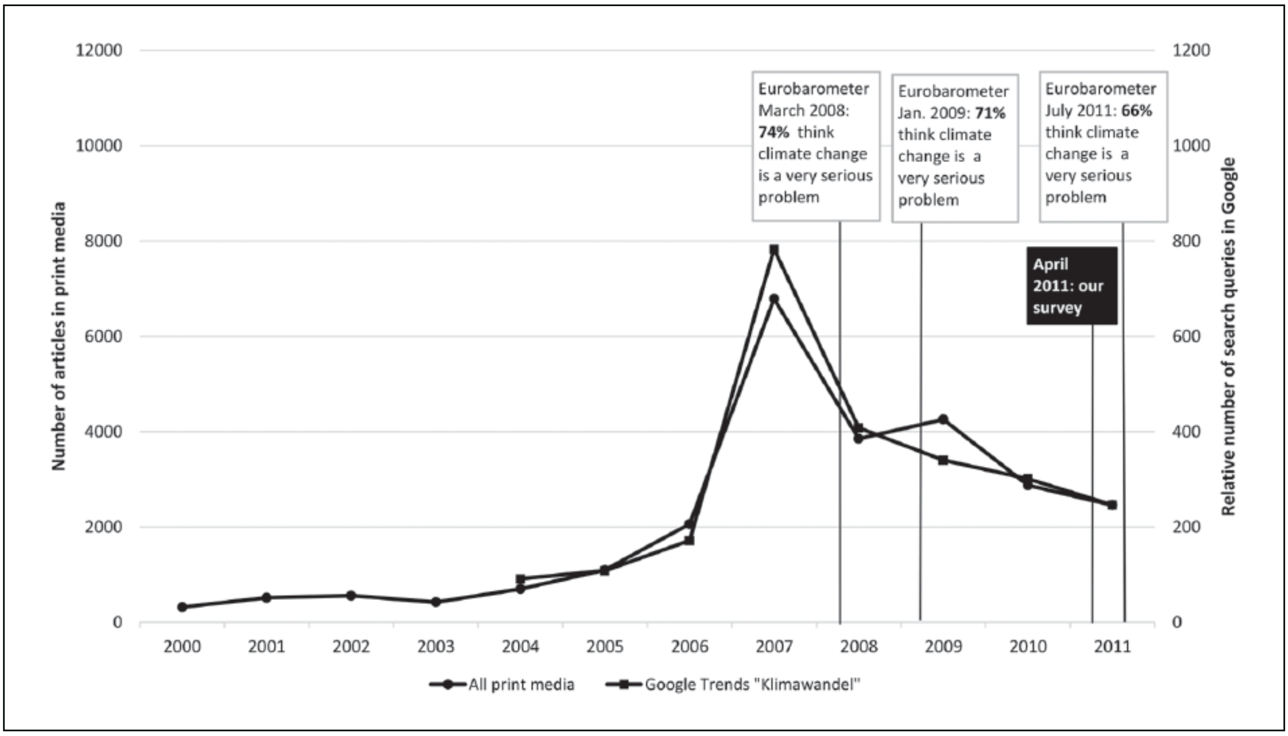


Figure 1. Issue attention for climate change in Germany. Print media articles (daily newspapers: Süddeutsche Zeitung, Frankfurter Allgemeine, taz, Frankfurter Rundschau, Welt; weekly newspapers: Focus, Spiegel) were searched in archives using the search terms "Klimawandel or Erderwärmung or globale Erwärmung or Treibhauseffekt". Data from Eurobarometer surveys is used to depict the development of the public's attitudes towards global warming. Google trends results are used as a measure fur public attention (Google trends figures are relative in the sense that Google trends depicts how often a search term is searched for during a period of time in comparison to all other Google searches. Thus, the data is normalized on a scale from 0 to 100. Each figure is divided by the maximum value and multiplied with 100. Google trends also only offers data back to 2004.)

on should be only slightly susceptible to changing contexts, since the segments are based on stable attitudes and values.

Operationalization

We aimed to operationalize as many of the relevant analytical dimensions for segmenting audiences according to their attitudes toward global warming that have been emphasized in the scholarly literature as possible. Since we performed a secondary analysis, however, we had to rely on the available survey questions. A total of 39 questions matched the dimensions outlined in section "Relevant dimensions for devising a typology of the German population" (see Table 1 for an overview). However, we did not capture all sub-dimensions that were part of the Global Warming's Six Americas or Australias studies.

We captured the following dimensions:

- *Beliefs about climate change* consist of multiple items. This dimension captures the direct acknowledgement of climate change as well as the role of climate science.
- To address *general environmental awareness*, multiple cognitive and affective items were used.
- We could not capture the *subjective norm* in its original sense but approximated it with two items that describe the *urgency of collective action*. In these items, however, the locus of control and who is supposed to act remain vague.

Table 1. Items used in our study and in reference studies.

Our survey	Global Warming's Six Americas (Maibach et al., 2011), also used in Australia (Morrison et al., 2013)
Beliefs about climate change "Climate change is man-made." (1 = *completely disagree* to 5 = *completely agree*; *M* = 4.01, *SD* = 1.05) "Climate research is of the unanimous opinion that global warming is real." (*M* = 3.98, *SD* = 1.06) "Climate change is currently happening." (*M* = 4.03, *SD* = 0.94) "Industrial countries like Germany are predominantly responsible for climate change." (*M* = 3.24, *SD* = 1.17) "Climate scientists can be trusted." (*M* = 3.27, *SD* = 1.01) *General environmental awareness* "Earth's living space and resources are highly limited." (1 = *completely disagree* to 5 = *completely agree*; *M* = 4.28, *SD* = 1.00) "The scope of the ecological crisis is being exaggerated." (*M* = 2.78, *SD* = 1.13) "Earth's natural balance can withstand pollution." (*M* = 2.58, *SD* = 1.15) "We are heading toward an environmental disaster." (*M* = 3.82, *SD* = 1.16) "Human beings are damaging the environment seriously." (*M* = 4.35, *SD* = 0.93) *Urgency of collective action* "It's important to take measures against climate change as soon as possible." (1 = *completely disagree* to 5 = *completely agree*; *M* = 4.46, *SD* = 0.89) "If one acts immediately climate change can be averted. (*M* = 2.94, *SD* = 1.16)" *Value dimensions* "We live at the expense of future generations." (*M* = 3.97, *SD* = 1.16) "In Germany, the enforcement of equal rights for everyone is being taken too seriously." (*M* = 2.83, *SD* = 1.18) "Individual freedom is too restricted in today's society." (*M* = 2.91, *SD* = 1.18) "Many problems can best be solved by individual people." (*M* = 2.82, *SD* = 1.30) "We are not doing enough to fight poverty in the world." (*M* = 3.54, *SD* = 1.26)	*Global warming beliefs* Certainty global warming is occurring Human causation (% agree) Scientific consensus (% agree) Personal risk Risk to future generations Risk to plant and animal species Timing of harm to Americans Ability of humans to successfully mitigate climate change Actions of individuals can make a difference Technological optimism Perceived impact of own mitigation actions Impact of own actions if widely adopted in the United States Impact of own actions if widely adopted in modern industrialized countries
Concern about climate change "Climate change is a serious problem." (*M* = 4.43, *SD* = 0.89) "Climate change causes an increase in extreme weather events." (*M* = 4.34, *SD* = 0.90) "I'm seriously worried about climate change." (*M* = 3.79, *SD* = 1.17) Personal affectedness by the worst impacts of climate change (1 = *yes* to 2 = *no*; *M* = 1.36, *SD* = 0.48) Region which has been most negatively impacted by climate change (1 = *close by* to 5 = *far away/other part of world*; *M* = 4.36, *SD* = 0.99) *Knowledge of climate change* "How well informed are you about climate change?" (1 = *not at all* to 5 = *very well*; *M* = 3.48, *SD* = 0.74)	*Global warming issue involvement* Rating of global warming (1 = *good* to 6 = *bad*) Worry about global warming Thought given to global warming Need for information (4 = *low need*) Personal importance of issue Unwilling to change opinion Personally experienced global warming Global warming discussion frequency Friends share views on global warming
Climate change–related behavior Refrain from car journeys (0 = *never* to 1 = *at least once*; *M* = 0.61, *SD* = 0.49) Refrain from plane journeys (*M* = 0.33, *SD* = 0.47) Bought energy-saving devices recently (*M* = 0.92, *SD* = 0.27) I've changed my electricity provider for ecological reasons (*M* = 0.20, *SD* = 0.40)	*Global warming and energy efficiency and conservation behaviors* Contacted govt officials about mitigation Rewarded companies that reduced emissions

(Continued)

Table 1. (Continued)

Our survey	Global Warming's Six Americas (Maibach et al., 2011), also used in Australia (Morrison et al., 2013)
Do you have an electricity rate that is fully or partly powered by ecological energy sources? (1 = *yes* to 0 = *no*; *M* = 0.60, *SD* = 0.49) Car use for shopping (1 = *never* to 6 = *daily*; *M* = 3.93, *SD* = 1.40) Car use for leisure activities (*M* = 3.64, *SD* = 1.49) Car use for driving to work (*M* = 3.94, *SD* = 2.28) Number of cars in household (*M* = 1.35, *SD* = 0.84) Kilometers per week by car (*M* = 225.73, *SD* = 422.47) *Political activism* Actively collecting signatures regarding energy issues (0 = *wouldn't ever* to 1 = *have done/might do*; *M* = 0.51, *SD* = 0.50) Participation in citizens' initiative regarding energy issues (*M* = 0.66, *SD* = 0.47) Participation in demonstrations regarding energy issues (*M* = 0.43, *SD* = 0.50) Joining an environmental organization (*M* = 0.45, *SD* = 0.50) Signing a petition regarding energy issues (*M* = 0.82, *SD* = 0.38) Donation for environmental organization (*M* = 0.67, *SD* = 0.47)	Intend to reward companies that reduce emissions Punished companies that are not reducing emissions Intend to punish companies that are not reducing emissions Stage of change for lowering thermostat in winter Stage of change for using public transportation or car pool Stage of change for walking/biking instead of driving Stage of change for CFL use
	Preferred societal response to global warming Priority of global warming for president and Congress Corporations should do more/less to reduce warming
	Citizens should do more/less to reduce warming Desired US effort to reduce warming, given associated costs Contingent int'l conditions for US mitigation action (% regardless of actions in other countries)
Mass media use and information seeking How often do you hear about climate change from the following sources? Television (*M* = 4.33, *SD* = 1.02), radio (*M* = 3.75, *SD* = 1.40), tabloids (*M* = 2.64, *SD* = 1.56), other daily newspapers (*M* = 3.76, *SD* = 1.39), weekly magazines and newspapers (*M* = 3.62, *SD* = 1.42), Internet (*M* = 3.45, *SD* = 1.24), conversations with friends and family (*M* = 4.33, *SD* = 1.02); 1 = *never* to 5 = *every week* On which source would you rely the most if in doubt? Television (38%), radio (7%), tabloids (0.3%), other daily newspapers (15%), weekly magazines and newspapers (14%), Internet (17%), conversations with friends and family (8%) To what extent would you say that this characteristic applies to this source: actuality (*M* = 4.33, *SD* = 0.79)/preciseness (*M* = 3.91, *SD* = 0.87)/balance (*M* = 3.71, *SD* = 0.94)/truthfulness (*M* = 3.43, *SD* = 0.88)? 1 = *not at all* to 5 = *very much*	*Mass media use and information seeking* How much attention do you pay to information about global warming? *A lot* to *None* In the past 30 days, how often have you actively looked for information about global warming? *A lot* to *None* How much do you trust or distrust the following as a source of information about global warming? *Strongly trust* to *Strongly distrust* How many days per week do you read a printed newspaper/listen to the radio …? How often do you watch or listen to the following shows or visit their websites? *Often* to *Never*

SD: standard deviation; CFL: compact fluorescent lamps.
The items used in the survey for the Six Indias are also available in Leiserowitz et al.'s (2013b) report. We refrain from listing them here as India as a developing country is very different from the United States, Australia, and Germany, and thus, the survey was adapted more intensively to this specific country.

- Several items covered *value* dimensions. These values are not ideological values but general values about how a society should function and whether one prefers individualistic or collectivistic ways of living. People with collectivistic values have been shown to be more engaged in fighting climate change.
- *Concern about climate change* comprises items that cover cognitive and affective components asking about the respondents' concern about climate change.
- *Knowledge of climate change* could not be measured through questions that captured the respondents' factual knowledge about global warming but through one item that measured the participants' individual perception of their knowledge.
- *Climate change–related behavior* was predominantly captured through energy conservation items.
- *Political activism* was accounted for by numerous questions concerning past environmental activities in which people had participated.

These items were entered into factor analysis to establish the dimensions the items cover (see Hefner, 2013; Sütterlin et al., 2011), which were then used as discriminating variables in the subsequent cluster analysis. In addition, the respondents' use of information about climate change was measured:

- To measure *mass media use*, participants were asked how often they get information about global warming from different types of mass media. Among these outlets, participants were asked to name the most reliable one and then to rate it in terms of *actuality, preciseness, balance*, and *truthfulness.* These variables describe the *perceived quality of media outlets*. The question about the frequency of getting information about climate change included information from "conversations with friends and family" which allows us to measure *interpersonal communication*.
- *Demographics* included age, sex, income, education (highest degree), people per household, whether the respondents had children, and whether the respondents were employed.

Typology

To ensure a concise solution for the cluster analysis, the 39 items were condensed into fewer independent constructs using principal axis factor analysis. Missing values were ignored case wise, and variables with loadings on multiple factors and/or loadings below .4 were excluded. Some variables with low commonalities were also removed. This led to a robust solution consisting of 26 items representing seven factors: Concern about climate change, political activism on energy issues, car use in everyday life, ecological conservatism, environmental concern, abstention from longer car/ plane journeys, and the use of eco-power (see Online Appendix for a detailed overview of the items loading on each factor).

Based on these seven factors, a hierarchical cluster analysis was conducted with the remaining 1943 cases.[2] First, the single-linkage method was applied that identified six outliers, which were then excluded from the sample. Based on these data, the cases were clustered using the Ward method and the elbow criterion to identify the best solution.[3] The five-cluster solution yielded the most differentiated coefficient and straightforward interpretation. A discriminant analysis was conducted to validate the cluster solution. The analysis yielded a rate of 81.1% of correctly identified cases, a value lower than those derived from content analytical data (e.g. Donk et al., 2012) but not atypical for attitude measures taken from survey data (Brosius, 2013). We also calculated F and t values that are helpful for interpreting which variables are distinctive for which cluster.

Table 2. Audience segments and the climate change–related dimensions.

	Alarmed	Concerned activists	Cautious	Disengaged	Doubtful
N (% of sample)	459 (24%)	345 (18%)	543 (28%)	389 (20%)	201 (10%)
Concern about climate change	**0.41**	0.13	0.16	0.18	**−1.60**
Environmental concern	**0.45**	−0.02	−0.14	**−0.19**	0.33
Car use	0.05	−0.04	**0.49**	**−0.39**	0.26
Abstention from longer car/plane journeys	**0.61**	0.30	**−0.65**	0.45	–0.15
Eco-power	**−0.42**	**1.75**	−0.37	−0.34	−0.12
Political activism on energy issues	**0.61**	0.28	0.30	**−0.93**	−0.48
Ecological conservatism	**−0.26**	−0.24	**0.26**	0.01	0.11

N = 1937. Lowest and highest scores per factor are shown in bold.

4. Global warming's five Germanys: Results

Attitude types among the German population

Table 2 shows that five clusters can be found among the German population. Similar to that of the United States, they span a broad range of attitudes.[4]

The first type, which we labeled the *Alarmed* (*n* = 459), scored the highest for being concerned about climate change and forms the second largest audience segment (24% of all respondents). The Alarmed are strongly concerned about climate change as well as the environment in general. Correspondingly, they are willing to abstain from longer car or plane journeys, do not use their cars more than averagely, and are politically active regarding energy issues. They are also the audience segment that most strongly believes ecological problems exist. However, although they are concerned about global warming and the environment, this concern does not extend to using eco-power.

The second cluster, the *Concerned Activists* (*n* = 345, 18%), are concerned about climate change—albeit less so than the Alarmed—and translate this concern into action. Their overall values point to environmentally friendly attitudes, they refrain from using cars and planes for longer journeys, and they show an above-average political activism tendency. Compared to the other types, this group are the only ones willing to use eco-power and the audience segment with the most environmentally friendly behavior.

The *Cautious* (*n* = 543, 28%) form the largest cluster. Although they appear to be concerned about climate change, their concern is not strong and does not translate into action. They use cars in everyday life, do not refrain from longer travel by car or plane, and do not use eco-power. We labeled them Cautious to convey their reluctance to behave in a climate-friendly manner (in the same way as Leiserowitz et al. (2009) used the label). The only aspect that mirrors their concern about global warming is their willingness to be politically active. This gap between attitude and behavior might be explained by the Cautious' conservative ecological values and their lack of worry about the environment in general. Although they are concerned about climate change, they do not strongly agree with statements that Earth's resources are limited or that we are living at the expense of future generations. This cluster, however, supports findings on climate change attitudes in Germany that show that although most citizens are convinced that climate change exists (Engels et al., 2013), this often fails to trigger corresponding behavior.

The *Disengaged* ($n=389$, 20%) are similar to the Cautious, but their disengagement is stronger. They are concerned about climate change but show the lowest environmental concern, and their ecological attitudes are not pronounced. They are not likely to use eco-power or to be politically active regarding climate change or energy issues. Their distinctive characteristic is that they entail the lowest number of people who have or use cars and that they would refrain from longer car or plane journeys.

The smallest audience segment are the *Doubtful* ($n=201$, 10%). They are not concerned about climate change at all and are skeptical that it exists or that it is caused by humans. This is mirrored in their behavior; they are neither likely to be involved in political activism nor are willing to switch to eco-power, reduce plane or car journeys, or stop using their car in everyday life. Similar to the Doubtful in the United States (Leiserowitz et al., 2009), doubtful Germans are conservative. However, they are not as environmentally ignorant as one might expect, since they still tend to believe that Earth's resources are limited and that humans are living at the expense of future generations.

Media use and information-seeking patterns

Global Warming's Five Germanys differ not only in their attitudes toward climate change. The German segments also differ socio-demographically and, most importantly for us, use different channels of communication (Table 3).

The Alarmed. With an average age of 50 years, 48% male, medium income and education, and between two and three people per household, the *Alarmed* represent the average German citizen.

The Alarmed are most concerned about climate change and the environment. And they are willing to give up certain living conveniences to do something about climate change. This is mirrored in their information and communication behavior. They are eager to receive information about climate change and search for it most frequently and significantly more often than the *Cautious, Disengaged*, and *Doubtful*. Although television is the Alarmed's primary source, they use all kinds of media frequently. They believe that television is the most reliable medium for information about climate change because they attribute up-to-date and precise news coverage to television. Respondents in this cluster also talk to family and friends significantly most often about climate change.

The Concerned Activists. With an average age of 48 years, this is the youngest cluster in our sample; 54% are male. The share of employed people and, correspondingly, the average income are the highest among all clusters, also indicating that they can afford to use eco-power.

This group exhibits above-average concern about climate change and more activism, which goes hand in hand with intensive information seeking about global warming. Similar to the other clusters, they use television most intensely, followed by newspapers and radio. Compared to the other audience segments, except the *Alarmed*, the Concerned Activists use the Internet more frequently for information about climate change. That these people are generally well informed and rely on more than one source can also be shown by the fact that they think weekly newspapers and magazines are the second most reliable sources for information about climate change.

The Cautious. This cluster contains more men (55%) than women, with an average age of 50 years, and a household size of three. Since 71.5% have at least one child, in this group, most respondents have children.

Although they are concerned about climate change, the Cautious scored only average in terms of information seeking about climate change. This is in line with their cautious, reluctant behavior regarding climate change. Among the five audience segments, this cluster uses television most

Table 3. Communication variables and demographics of cluster types.

	Alarmed	Concerned Activists	Cautious	Disengaged	Doubtful
N	459	345	543	389	201
Demographics					
Male (in %)	47.50	54.0	55.0	47.60	65.70
Age	49.6	48.44^{b}	50.2	52.54^{ab}	47.72^{a}
Higher education (in %) (qualification for university of applied sciences or above)	28.7	33.8	21.7	15.9	28.9
Household income (3000 Euros or more) (in %)	24.8	34.0	24.5	12.4	31.3
Employment (in %)	53.8	67.3	63.5	46.1	64.7
Persons per household	2.57	2.60	2.76^{a}	2.32^{ab}	2.95^{b}
At least 1 child (in %)	66.9	71.0	71.5	69.2	69.5
Media use[1]					
TV use	4.41^{a}	4.36	4.42^{b}	4.33	4.11^{ab}
Radio use	4.00^{a}	3.92^{b}	3.78	3.50^{ab}	3.69
Tabloids use	2.85	2.63	2.90^{a}	3.02^{b}	2.39^{ab}
Other daily newspaper use	3.89	3.92	3.83	3.70	3.62
Weekly magazines and newspapers use	3.93^{ab}	3.72	3.62^{a}	3.51^{b}	3.58
Internet use	3.60^{ab}	3.50	3.20^{a}	3.02^{b}	3.25
Conversations with friends and family	3.82^{abc}	3.66^{de}	3.40^{af}	3.20^{be}	2.95^{cdf}
Most reliable media	TV (33.3%) Internet (17.8%)	TV (27.8%) Weekly magazines/ newspapers (18.4%)	TV (46.2%) Internet (15.5%)	TV (44.1%) Internet (18.4%)	TV (37.3%) Internet (18.7%)
Quality of most reliable source[2]					
Actuality	4.39	4.29	4.36	4.25	4.31
Preciseness	4.11^{acd}	3.80^{ab}	3.86^{c}	4.06^{be}	3.75^{de}
Balance	3.79	3.74	3.82	3.81	3.53
Truthfulness	3.64^{a}	3.45	3.40^{a}	3.44	3.53
Frequency of researching information about climate change[3]	3.17^{abc}	3.00^{def}	2.67^{adg}	2.51^{be}	2.34^{cfg}

Figures are means if not otherwise indicated. Means in the same row that share superscripts differ at $p < .05$ in the post-hoc test (Scheffé).
$N = 1937$.
[1]"How often do you hear about climate change from these information sources?" 1 = *never* to 5 = *every week*.
[2]"To what extent would you say that this characteristic applies to this source of information?" 1 = *not at all* to 5 = *very much*.
[3]"How frequently do you seek information about climate change?" 1 = *never* to 5 = *very often*.

frequently for information about the issue and perceives television as the most reliable medium. Regarding all other types of mass media as well as interpersonal communication about climate change, the Cautious show average usage.

The Disengaged. This group is not only disengaged from the issue of climate change but also differs in other respects from other audience segments; 52% of the respondents are female, and with an average age of 53 years, they are significantly older than the *Concerned Activists* and the *Doubtful*. The Disengaged also have the smallest average household-size and low education levels, and more than half (53.9%) are unemployed. Consequently, the Disengaged also have the lowest average income. This might also explain why they do not use cars and abstain from longer car or plane journeys: not out of concern about the environment (which is low), but because they cannot afford them.

The Disengaged do not seek information about climate change very often. If they do, they mainly use TV and tabloid newspapers, with all other media being used clearly below average. This group avoids media outlets that are more information-oriented and entail more complex reporting. In addition, this group barely talks about global warming.

The Doubtful. In this segment, the highest share of male respondents (66%) can be found, with an average age of 48 years. Most work full-time, have a high income, and have one or more children, which might explain why they are skeptical about climate change yet still concerned about the environment: they are concerned about the limited resources on Earth and future generations.

People in this segment doubt climate change exists and scored the lowest on information seeking. They search for information about climate change significantly less frequently than the *Alarmed, Concerned Activists*, and *Cautious*. If this group receives such information at all, it reaches them via TV, the daily newspaper, or the radio. They believe that television and the Internet are the most reliable sources of information about climate change because these media outlets present information that is most up-to-date. Among the five audience segments, this segment talks the least about climate change with their family or friends.

5. Summary and discussion

The aim of our study was to establish whether the German population can be segmented into attitude types regarding climate change and to what extent these types differ in media use and information-seeking patterns. We show that the German public can be categorized into five types: the *Alarmed*, the *Concerned Activists*, the *Cautious*, the *Disengaged*, and the *Doubtful*.

In Figure 2, our results are compared to the US (Leiserowitz et al., 2009), Australian (Morrison et al., 2013), and Indian studies (Leiserowitz et al., 2013b), albeit with some caution. Since this study was a secondary analysis, we could not use the same items used in the US study and had to rely on cluster analysis, which was also used in the Indian study but not in the US or Australian studies (they used latent class analysis).

With these limitations in mind, the German population has the biggest group of Alarmed people among the four countries. Compared to Leiserowitz et al.'s (2009) study of the American public, the German audience is generally more concerned about climate change, as four out of the five audience segments show a higher-than-average concern about climate change.

In contrast, the *Dismissive* segment—which existed in the United States and Australia and believed most strongly that climate change is not occurring or not caused by humans—does not exist in Germany. Although the German *Doubtful* are also unconcerned about climate change, they still show concern for the environment in general (unlike the *Dismissive* in the United States or

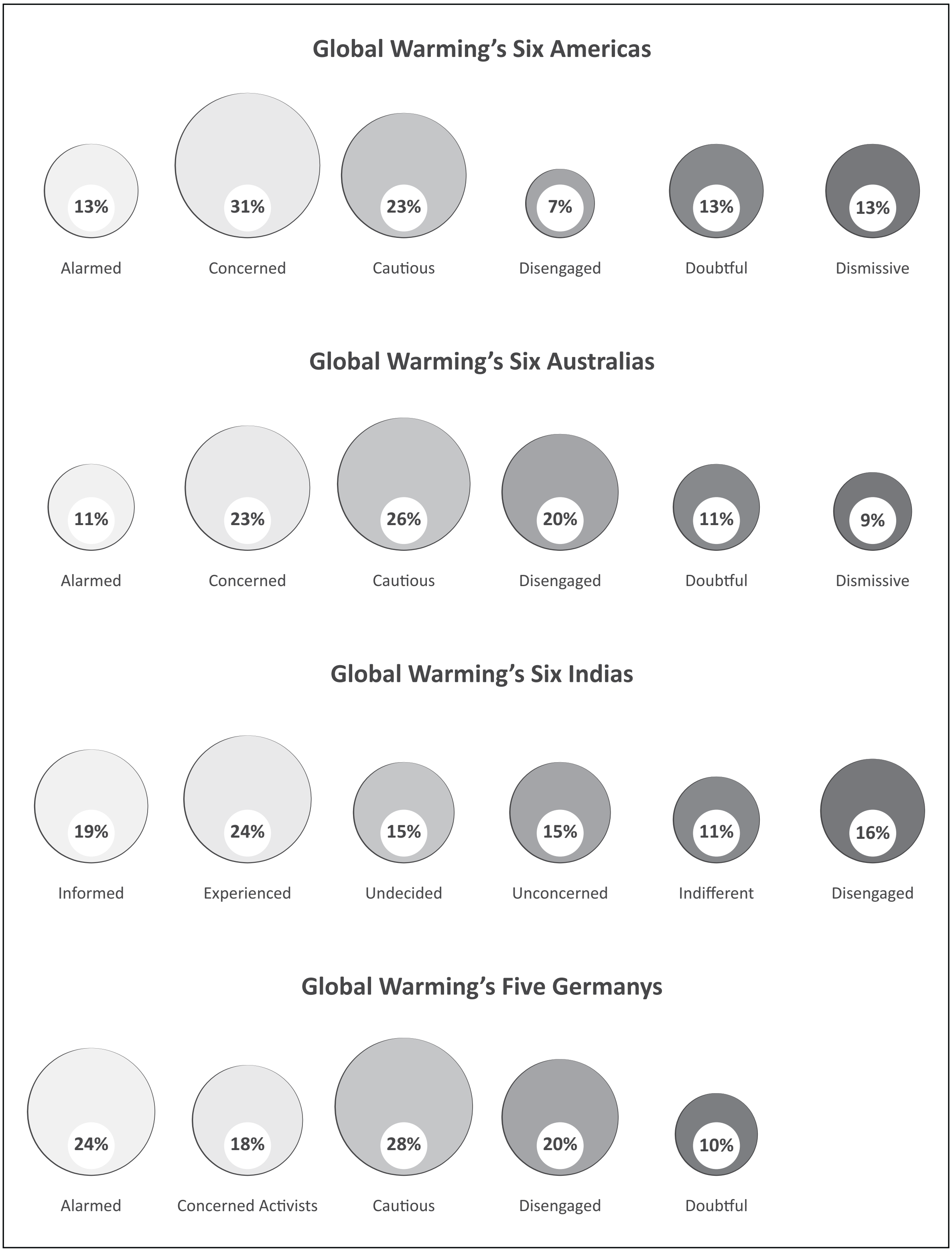


Figure 2. Audience segments in different countries (data are retrieved from Leiserowitz et al. (2013b, 2014) and Morrison et al. (2013)). Comparability of the segments is limited as there are differences in survey items and data analysis between the countries.

Australia). This underscores that climate change skepticism is not as widespread in Germany as it is in Anglo-Saxon countries (Engels et al., 2013).

The differentiation of the public also holds true for the ways people get information about global warming. Although all types use television as the main source of information about climate change (Schäfer, 2012), the analysis shows that the *Alarmed* search for information in the mass media and talk about the issue most frequently. The *Doubtful*, in contrast, search least for climate change information. This is similar to the US results in which the *Alarmed* follow news on climate change closely and the *Doubtful* barely seek out information about the issue (Leiserowitz et al., 2009: 28).

These results are relevant not only for the scientific study of attitudes toward climate change. The results might also be useful for communication campaigns to raise people's awareness of and actions toward climate change, as they indicate the ways in which the different types must be addressed.

The three groups least concerned about climate change or least taking actions against global warming are the *Doubtful*, the *Disengaged*, and the *Cautious*. Although television is the main source of climate change information for these types as well, they still need to be addressed differently. With the *Doubtful*, a campaign on global warming should be aimed at raising their concern about climate change and reducing their doubts about ongoing global warming—a difficult task but perhaps not a completely hopeless endeavor, since this group shares a certain amount of environmental concern. The communication pattern of this type indicates that they do not look for information about climate change intentionally but come across it during their everyday, routine media use. They can be addressed if they are confronted with information about climate change unexpectedly on television, as "by-catch" while watching something else.

The *Disengaged* are not really skeptical about global warming. However, they do not engage much in environmentally friendly behavior, perhaps due to their lower social status, especially their low income. They should be addressed with basic information about climate change, since they are not well informed, in communication campaigns that are easily understandable and stress inexpensive methods for changing behavior. Since the Disengaged use tabloids, they might respond better to entertainment or fictional formats, such as movies like *The Day after Tomorrow*, which, however, tend not to have long-lasting effects (Hart and Leiserowitz, 2009; Leiserowitz, 2004). This group, however, may not be addressed at all through communication campaigns, because the Disengaged are not interested in the issue (cf. Hefner, 2013 for environmental protection). Behavioral changes among the Disengaged may have to be triggered by financial incentives, taxes, and so on.

The *Cautious* are aware of climate change as a problem but must be motivated to change their behavior accordingly. Communication campaigns should focus on mobilizing information and provide information about behavioral options in everyday life (e.g. refraining from using a car or using eco-power) to mitigate climate change. To increase this group's concern about the environment, information about environmental problems in general should be included.

People in one of the other two audience segments of the German public are more likely to be concerned about climate change. They look for information about climate change more frequently and could be addressed via multiple media outlets. Concern about global warming should be increased for the *Alarmed* in a campaign that focuses on inexpensive ways to behave environmentally friendly since this group is hesitant to use more expensive methods such as eco-power. These people could potentially function as opinion leaders as they talk about climate change quite often (they seem to mirror the "mediatized opinion leaders" on climate change found in Schäfer and Taddicken (2015)). A campaign should provide information about climate change that is easy to communicate further to other people.

The *Concerned Activists* are young and more affluent. These people are concerned about climate change but not as much about the environment in general. If a campaign convinces them of the broader environmental implications of climate change, their general environmental concern might increase, and these people might become even more engaged and could serve as role models for others. Information should be provided not only on television and the Internet but also in print media since these outlets are perceived as reliable and trustworthy.

These findings are in line with recent studies on climate change–related attitudes in Germany (e.g. Engels et al., 2013; European Commission, 2014) and with attitude-based typologies on related issues such as the environment (Hefner, 2013). Still, these findings must be confirmed in the future since our study has several limitations. We could not operationalize all dimensions that might have been relevant. For example, it would have been useful to know whether the different segments use media more for information or entertainment. In addition, further information about the kind of people they talk to about global warming would also be relevant, since conversations with family and friends might differ from conversations with colleagues at work. In a similar fashion, a more differentiated study of what kind of information citizens use on the Internet would have strengthened the analysis. The next step should be to actually test the use and effects of information about climate change for these different audience segments to analyze if communication effects also differ between the types of climate change attitudes.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The data used in this study was funded by by the German Research Council DFG through the Cluster of Excellence "Integrated Climate System Analysis and Prediction (CliSAP)'', EXC 177, University of Hamburg.

Notes

1. The data contained some over- or under-representations. Therefore, some cases were weighted: people over 60 years were slightly underrepresented (33.7% in the data vs 38.4% in the German population), women were slightly overrepresented (55.1% vs 51.3%), and people with a tertiary education were over-represented (20.5% vs 9.5%).
2. The sample size was reduced because only cases with no missing variables have a factor value attributed. The reduced sample was checked for skewed distributions of variables, which ensured that the remaining sample was not biased in any direction.
3. The Ward method was also used in the Six India's study (Leiserowitz et al., 2013b). The US and Australian typologies, however, are based on latent class analysis, which must be taken into account when the results of this study are compared.
4. We organized our typology primarily along these attitude types instead of, for example, Germans' willingness to act upon climate change. This mirrors the US, Australian, and Indian studies. However, it must be emphasized that even if the segments have similar names, differences between the countries' segments remain. For example, the belief that climate change is occurring is stronger in the Alarmed, Concerned, and Cautious groups in Australia than in the same segments in the United States (Morrison et al., 2013).

References

Ajzen I (1989) Attitude structure and behavior. In: Pratkanis AR, Breckler SJ and Greenwald AG (eds) *Attitudes and Persuasion*, vol. 3. Hillsdale, NJ: Erlbaum, pp. 241–274.

Arlt D, Hoppe I and Wolling J (2011) Climate change and media usage: Effects on problem awareness and behavioral intentions. *International Communication Gazette* 73(1–2): 45–63. DOI: 10.1177/1748048510386741.

Bamberg S and Möser G (2007) Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. *Journal of Environmental Psychology* 27(1): 14–25. DOI: 10.1016/j.jenvp.2006.12.002.

Brosius F (2013) *SPSS 21*. Heidelberg: mitp.

Cabecinhas R, Lázaro A and Carvalho A (2008) Media uses and social representations of climate change. In: Carvalho A (ed.) *Communicating Climate Change*. Braga: CECS/Universidade do Minho, pp. 170–189.

Diekmann A and Preisendörfer P (2003) Green and greenback: The behavioral effects of environmental attitudes in low-cost and high-cost situations. *Rationality and Society* 15(4): 441–472. DOI: 10.1177/1043463103154002.

Donk A, Metag J, Kohring M and Marcinkowski F (2012) Framing emerging technologies. Risk perceptions of nanotechnology in the German press. *Science Communication* 34(1): 5–29.

Engels A, Hüther O, Schäfer M and Held H (2013) Public climate-change skepticism, energy preferences and political participation. *Global Environmental Change* 23: 1018–1027. DOI: 10.1016/j.gloenvcha.2013.05.008.

European Commission (2014) *Special Eurobarometer 409: Climate Change*. Available at: http://ec.europa.eu/public_opinion/archives/ebs/ebs_409_en.pdf

Hart PS and Leiserowitz AA (2009) Finding the teachable moment. *Environmental Communication* 3(3): 355–366. DOI: 10.1080/17524030903265823.

Hefner D (2013) "Wie kriegen wir sie ins Boot?" Eine Typologie zur Entwicklung von Kommunikationsstrategien zur Förderung umweltschützen Verhaltens ["How do get them on board?" A typology to develop communication strategies to foster environmental-friendly behavior]. *Medien & Kommunikationswissenschaft* 61(3): 387–405.

Leiserowitz A (2004) Before and after The Day After Tomorrow: A U.S. study of climate change risk perception. *Environment* 46(9): 22–37.

Leiserowitz A, Maibach E, Roser-Renouf C and Smith N (2009) *Global Warming Six Americas 2009*. Available at: http://environment.yale.edu/climate-communication/files/climatechange-6americas.pdf

Leiserowitz A, Maibach E, Roser-Renouf C, Feinberg G and Howe P (2013a) *Global Warming's Six Americas: September 2012*. Available at: http://environment.yale.edu/climate/publications/Six-Americas-September-2012

Leiserowitz A, Maibach E, Roser-Renouf C, Feinberg G and Rosenthal S (2015) *Climate Change in the American Mind: March 2015*. Fairfax, VA: George Mason University and New Haven, CT: Yale Project on Climate Change Communication, Yale University.

Leiserowitz A, Maibach E, Roser-Renouf C, Feinberg G, Rosenthal S and Marlon J (2014) *Global Warming's Six Americas: October 2014*. Fairfax, VA: George Mason University and New Haven, CT: Yale Project on Climate Change Communication, Yale University.

Leiserowitz A, Thaker J, Feinberg G and Cooper D (2013b) *Global Warming's Six Indias*. Available at: http://environment.yale.edu/climate-communication/article/Global-Warming-Six-Indias

McCright AM and Dunlap RE (2011) Cool dudes: The denial of climate change among conservative white males in the United States. *Global Environmental Change* 21(4): 1163–1172. DOI: 10.1016/j.gloenvcha.2011.06.003.

Maibach EW, Leiserowitz A, Roser-Renouf C and Mertz CK (2011) Identifying like-minded audiences for global warming public engagement campaigns. *PLoS ONE* 6(3): e17571. DOI: 10.1371/journal.pone.0017571.

Morrison M, Duncan R, Sherley C and Parton K (2013) A comparison between attitudes to climate change in Australia and the United States. *Australasian Journal of Environmental Management* 20(2): 87–100. DOI: 10.1080/14486563.2012.762946.

Moser SC (2010) Communicating climate change. *WIREs Climate Change* 1(1): 31–53. DOI: 10.1002/wcc.11.

Nisbet MC and Myers T (2007) The polls trends: Twenty years of public opinion about global warming. *Public Opinion Quarterly* 71(3): 444–470. DOI: 10.1093/poq/nfm031.

O'Keefe DJ (1990) *Persuasion*. Newbury Park, CA: SAGE.

Peters HP and Heinrichs H (2008) Legitimizing climate policy: The `risk construct' of global climate change in the German mass media. *International Journal of Sustainability Communication* 3: 14–36.

Sampei Y and Aoyagi-Usui M (2009) Mass-media coverage, its influence on public awareness of climate-change issues, and implications for Japan's national campaign to reduce greenhouse gas emissions. *Global Environmental Change* 19(2): 203–212. DOI: 10.1016/j.gloenvcha.2008.10.005.

Schäfer MS (2012) „Hacktivism"? Online-Medien und Social Media als Instrumente der Klimakommunikation zivilgesellschaftlicher Akteure ["Hacktivism?" Online and social media as tools of climate communication of civil actors]. *Forschungsjournal Neue Soziale Bewegungen* 25(2): 68–77.

Schäfer MS (2015) Climate change and the media. In: Wright JD (ed.) *International Encyclopedia of the Social & Behavioral Sciences*, vol. 3, 2nd edn. Oxford: Elsevier, pp. 853–859.

Schäfer MS and Taddicken M (2015) Mediatized opinion leaders: New patterns of opinion leadership in new media environments? *International Journal of Communication* 9. Available at: http://ijoc.org/index.php/ijoc/article/view/2778/1351

Schäfer MS, Ivanova A and Schmidt A (2014) What drives Media attention for climate change? Explaining issue attention of Australian, German and Indian Print Media from 1996 to 2010. *International Communication Gazette* 76(2): 152–176. DOI: 10.1177/1748048513504169.

Schmidt A, Ivanova A and Schäfer MS (2013) Media attention for climate change around the world: A comparative analysis of newspaper coverage in 27 countries. *Global Environmental Change* 23(5): 1233–1248.

Sherley C, Morrison M, Duncan R and Parton K (2014) Using segmentation and prototyping in engaging politically-salient climate-change household segments. *Journal of Nonprofit & Public Sector Marketing* 26(3): 258–280. DOI: 10.1080/10495142.2014.918792.

Sütterlin B, Brunner TA and Siegrist M (2011) Who puts the most energy into energy conservation? A segmentation of energy consumers based on energy-related behavioral characteristics. *Energy Policy* 39(12): 8137–8152. DOI: 10.1016/j.enpol.2011.10.008.

Taddicken M (2013) Climate change from the user's perspective. *Journal of Media Psychology* 25(1): 39–52.

Taddicken M and Neverla I (2011) Klimawandel aus Sicht der Mediennutzer: Multifaktorielles Wirkungsmodell der Medienerfahrung zur komplexen Wissensdomäne Klimawandel [Climate change from the perspective of media users: A multifactorial effects model on media experience with the complex issue climate change]. *Medien & Kommunikationswissenschaft* 59: 505–525.

UN News Centre (2014) *Opening Remarks at 2014 Climate Summit*. Available at: http://www.un.org/apps/news/infocus/sgspeeches/statments_full.asp?statID=2355#.VC5suxDKWno

Vicente P and Reis E (2007) Segmenting households according to recycling attitudes in a Portuguese urban area. *Resources, Conservation and Recycling* 52(1): 1–12. DOI: 10.1016/j.resconrec.2007.01.005.

Zhao X (2009) Media use and global warming perceptions: A snapshot of the reinforcing spirals. *Communication Research* 36(5): 698–723. DOI: 10.1177/0093650209338911.

Author biographies

Julia Metag is a senior research and teaching associate at the University of Zurich's Institute of Mass Communication and Media Research (IPMZ), Switzerland. Her research focuses on political communication, science communication, and media effects.

Tobias Füchslin is a Student Associate at the University of Zurich's Institute of Mass Communication and Media Research (IPMZ). His interests are science communication, statistical analysis, and scientific methodology.

Mike S. Schäfer is Professor for Science Communication at the University of Zurich's Institute of Mass Communication and Media Research (IPMZ). His research focuses on climate change communication, online communication, and the mediatization of science.

7.5 Füchslin (2019)

Science communication scholars use more and more segmentation analyses: Can we take them to the next level?

Füchslin, T.

This article was originally published in:

Füchslin, T. (2019). Science communication scholars use more and more segmentation analyses: Can we take them to the next level? *Public Understanding of Science (Bristol, England)*, *28*(7), 854-864. https://doi.org/10.1177/0963662519850086

Commentary

P | U | S

Public Understanding of Science
2019, Vol. 28(7) 854–864

DOI: 10.1177/0963662519850086
journals.sagepub.com/home/pus
SAGE

Science communication scholars use more and more segmentation analyses: Can we take them to the next level?

Tobias Füchslin
University of Zürich, Switzerland

Abstract
Science communication scholars are publishing more and more segmentation analyses as they further our understanding of different audiences and their characteristics. They follow different aims, are therefore difficult to compare and do not lend themselves to more generalisable and theoretical knowledge production. Our field has the potential to follow a demand for more systematic efforts by taking advantage of our high-quality representative data sets focusing on public perceptions of science. Beforehand, however, science communication scholars using segmentation analyses have to identify common goals and overcome a number of hurdles concerning variable selection, methodological approaches, and transparency. Ultimately, a collaborative and systematic application of segmentation analyses could result in truly relevant insights for our field.

Keywords
cluster analysis, public understanding of science, science communication, segmentation, survey research

Science communication has developed an appetite for segmentation analyses. For a long time, scholars predominantly analysed the wealth of nationally representative data sets on people's perceptions of, attitudes towards and knowledge of science through multivariate analyses such as linear regression models (Bauer, 2009). They give insights into variable relationships but do not further our understanding of different audiences of science communication and their characteristics. That is why our field needs segmentation analyses – a form of explorative data analysis that divides a population that is diverse in analytically relevant characteristics into relatively homogeneous, yet mutually exclusive subgroups (Metag and Schäfer, 2018). This journal published a first peer-reviewed segmentation analysis of nationally representative survey data in the field of science communication, outlining that the Japanese population can be interpreted as four distinct

Corresponding author:
Tobias Füchslin, Department of Communication and Media Research (IKMZ), University of Zürich, Andreasstr. 15, CH-8050 Zürich, Switzerland.
Email: t.fuechslin@ikmz.uzh.ch

and relatively homogeneous segments called 'Inquisitive', 'Sciencephiles', 'Life-centred' and 'Low-interest' (Kawamoto et al., 2011). Before, similar analyses were only found in non-academic reports such as a series of segmentations of the UK population (e.g. Ipsos MORI, 2011; OST & Wellcome Trust, 2000). Since then, however, more and more segmentation analyses were published in research journals like *Public Understanding of Science* (PUS), *Environmental Communication* and the *Journal of Science Communication*. Just recently, *PUS* was part of a burst of segmentations starting in 2016, including analyses for South Africa (Guenther and Weingart, 2017), Switzerland (Schäfer et al., 2018), Japan (Okamura, 2016) as well as China, South Korea and the United States (Pullman et al., 2018). Complementing this burst, a special issue on 'Audience Segments in Environmental and Science Communication' was published in *Environmental Communication* (Metag and Schäfer, 2018).

It is noticeable that these segmentations (cf. Table 1) mostly follow different aims, are therefore difficult to compare and do not lend themselves easily to generalisation.[1] Most of these studies do not aim to build a body of systematic knowledge but have more practical aims and, therefore, are not motivated by a common set of goals and are also less theoretically driven. Some studies heavily focus on country comparisons (Pullman et al., 2018), some on temporal developments within the same country (Okamura, 2016), whereas others aim to improve science communication efforts in general (Schäfer et al., 2018), to recruit potential citizen scientists (Füchslin et al., 2019), to increase people's scientific literacy (Kawamoto et al., 2011), or by offering efficient 'post hoc' segmentations (Runge et al., 2018). Against this backdrop, Scheufele (2018) recently demanded that fields like science and environmental communication strive for more systematic segmentation efforts, taking into account differences between issues, issue cycles, cultural or national contexts and methodological approaches. He suggests that such efforts would be valuable for basic social science research and not only for specific communication purposes.

Science communication research is ideally suited to realise such systematic efforts: First, science communication is still in the early phase of employing segmentation analyses. This allows us to think about systematic efforts before different research groups are set in their incomparable ways. Second, our field has established many nationally representative surveys like the annual 'Science and Engineering Indicators' in the United States, the 'Eurobarometer' or the 'Wissenschaftsbarometer' in Germany or Switzerland (for an overview, compare Bauer and Falade, 2014). This means that researchers can draw on a lot of high-quality survey data, some of them available for several countries and cross-national comparative analysis, and some of them available over long periods of time, partly for decades. Third, most of these surveys already have substantial topical overlap. Almost all of them assess people's attitudes towards, knowledge of and perceptions of science and often share measurements of a handful of key theoretical dimensions (cf. Bauer, 2009; Besley, 2013). While there remain crucial differences between these surveys – some ask about 'science & technology', others about 'science and research' – the overlap is big enough to identify a common topic like 'public perceptions of science'.

This creates a situation where researchers have high-quality data, can focus on a common topic and start using segmentation analyses by systematically varying national and temporal contexts. Segmentation analyses in climate change communication have already shown that proposed segmentation solutions of one country can be directly applied to another country (Morrison et al., 2013), or tracked across time within the same country (Morrison et al., 2018). Science communication could mimic and even surpass such efforts.

Beforehand, however, segmentation analyses in science communication have to overcome a number of hurdles. I will outline why and how we need to (a) streamline variable selection and measurement, (b) focus on methodological approaches that favour robust solutions, and (c) improve transparency and facilitate continued efforts. I make my points by focusing on prior segmentation

Table 1. Overview of representative segmentation analyses in science communication.

Study	Topical focus	Aim of segmentation (additional analyses are not considered)	Sample	Number of items	Method	Robustness checks	Results	Directly related studies
Füchslin et al. (2019)	Interest to participate in citizen science projects	Reconstructing target groups for citizen science projects; improving communication of recruitment	National representative survey, subset (*N* = 381) Switzerland, 2016	13 items (dichotomous and 5-point) covering demographics and attitudes towards science and research	Latent class analysis	Within-method statistical robustness Not across methods	Five segments: 'Free-Timers', 'Senior Sciencephiles', 'Young Sciencephiles', 'Intrigued Adolescents' and 'Fully Employed Parents'	–
Pullman et al. (2018)	Attitudes towards science & technology	Contribute to international comparative research	World Value Survey, sixth wave: USA (*N* = 2159), China (*N* = 1580), South Korea (*N* = 1145), Japan (*N* = 1847)	6 items (10-point) covering general attitudes towards science & technology	Latent class analysis (limited to 5 classes)	Not reported	Five recurring segments: 'High-positive', 'Moderate', 'Negative', 'Moderate-Positive' and 'Negative & Positive' At least two segments represented in each country	–
Runge et al. (2018)	Science communication	Post hoc creation of segments for science communication researchers and practitioners	National representative survey (*N* = 2858) USA, 2014	5 items (7/11-point) covering ideologies and attitudes towards scientists	Hierarchical clustering	Within-method statistical robustness Not across methods	Five segments: 'Protective progressives', 'Engaged moderates', 'Mainstream traditionalists', 'Disengaged moderates' and 'Distrustful traditionalists'	–
Besley (2018)	Views about science and technology	Trying to understand views about science and technology using segmentation	National representative survey (*N* = 1266) USA, 2016	11 items (wide range of scales) covering demographics, ideology, attitudes towards science and technology	Latent profile analysis	Not reported	Six segments: 'Disengaged', 'Worried', 'Cautious Conservatives', 'Moderate Optimists', 'Liberal Sciencephiles' and 'Conservative Sciencephiles'	–
Schäfer et al. (2018)	Attitudes towards science and research	Reconstructing audiences of science communication; improving science communication	National representative survey (*N* = 1051) Switzerland, 2016	20 items (5-point) covering attitudes towards science and research	Latent class analysis	Compared to factor analysis plus hierarchical cluster analysis	Four segments: 'Sciencephiles', 'Critically Interested', 'Passive Supporters' and 'Disengaged'	Short-scale development (Füchslin et al., 2018)

(Continued)

Table 1. (Continued)

Study	Topical focus	Aim of segmentation (additional analyses are not considered)	Sample	Number of items	Method	Robustness checks	Results	Directly related studies
Cámara et al. (2018)	Public perception of science & technology	Providing evidence of the group of the 'Critical Engagers'	National representative survey (N = 6354) Spain, 2014	4 items (3-/5-point) covering support of and optimism towards science	Manual attribution	N.A.	Two segments: 'Critical Engagers' and 'Others'	–
Guenther and Weingart (2017)	Attitudes towards science & technology	Investigating cultural context of attitudes towards science and technology	National representative survey (N = 3183) South Africa, 2010	30 items (dichotomous) covering sociodemographics, science information sources and scientific literacy	Hierarchical cluster analysis	Not reported	Six sociodemographic segments	Qualitative follow-up (Guenther et al., 2018)
Okamura (2016)	Attitudes towards science & technology policymaking	Enhancement of understanding of audiences regarding science & technology policymaking; temporal comparisons	National representative survey (N = 6136) Japan, 2011	3 items (4-point) regarding attitudes towards science & technology policy	K-means cluster analysis to reconstruct three conceptualised segments	Clusters remained stable over 8 months (eight waves)	Three segments: 'Attentive', 'Interested', 'Residual'	–
Castell et al. (2014)	Attitudes towards science & technology	Continued reporting on attitudes towards science	National representative survey (N = 1749) UK, 2013	77 items (5-point) covering general attitudes towards science & technology Condensed into 15 factors representing 76 items	Factor analysis K-means cluster analysis	Not reported	Six segments: 'Late Adopters', 'Concerned', 'Disengaged Sceptics', 'Indifferent', 'Distrustful Engagers' and 'Confident Engagers'	Predecessor UK segmentations (Ipsos MORI, 2011; MORI, 2005; OST and Wellcome Trust, 2000; Research Councils UK, 2008)
Nisbet and Markowitz (2014)	Beliefs about science and society	Investigating influence of beliefs about science and society on public opinion about stem cell research	Eight waves of national representative surveys (N = 8105) USA, 2002–2010 (excluding 2009)	4 items (4-point) covering hopes and reservations towards science Condensed into two factors	Manual attribution	N.A.	Four segments: 'Scientific Optimists', 'Scientific Pessimists', 'Conflicted' and 'Disengaged'	–

(Continued)

Table 1. (Continued)

Study	Topical focus	Aim of segmentation (additional analyses are not considered)	Sample	Number of items	Method	Robustness checks	Results	Directly related studies
Ipsos MORI (2013)	Attitudes towards science & technology	Commissioned report: explore current attitudes towards science and technology and biotechnology	National representative survey (N = 2000) Australia, 2012	14 items (11-point) covering general attitudes towards science & technology	K-means cluster analysis	Not reported	Four unnamed segments	–
Hurtado and Cerezo (2012)	Public perception of science & technology	General analysis of scientific culture	Pseudo-representative sample (N = 7739) Region of Ibero-America, 2007	11 items (3-/4-point) covering attitudes towards science and technology	Hierarchical cluster analysis	Not reported	Three unnamed segments	–
Kawamoto et al. (2011)	Science Communication Scientific literacy	Improving science communication to enhance scientific literacy	National representative survey (N = 1286) Japan, 2008	65 items covering social, literacy and science questions Condensed into three factors representing 38 items	Factor analysis K-means cluster analysis	Not reported	Four segments: 'Inquisitive', 'Sciencephiles', 'Life-centred' and 'Low-interest'	Representation of segments at science café events (Kawamoto et al., 2013)
Sweeney Research (2011)	Attitudes towards and engagement with science and technology	Tracking community attitudes to and engagement with science	Community representative survey (N = 800) Victoria, Australia, 2011	3 items (scale unclear) covering interest in and information seeking of science and technology	Manual attribution	N.A.	Six unnamed segments	Inaccessible predecessor segmentation in 2007 Focus group study with uninterested segment (Cormick, 2012)

analyses in science communication (or closely related fields) that work with representative data sets exclusively (cf. Table 1).

1. We need to streamline variable selection and measurement

Ideally, a clear theoretical framework guides variable selection in any systematic approach to segmentation analyses. But Hine et al. (2014) observed many ‘atheoretical’ approaches to variable selection in climate change communication segmentations. Analyses in science communication are mostly isolated undertakings, minimising researchers’ need and effort to develop a theoretical framework. As a result, analyses show differences on at least *four levels*. As Metag and Schäfer (2018) point out, a *first level* of differences pertains to whether researchers segment along psychographic, sociodemographic or behavioural variables. Segmentations in science communication are quite similar in that they mostly employ a psychographic approach focusing on attitudes towards science (and technology/research). Some studies, however, go beyond these variables and add sociodemographics (Besley, 2018), behavioural variables like media consumption (Kawamoto et al., 2011) or both (Guenther and Weingart, 2017). A *second level* of differences appears in the number and selection of theoretical dimensions. For example, Pullman et al. (2018) focus on the single dimension of general attitudes towards science, while other studies conceptualise attitudes towards science through as many as five dimensions, covering cognitive, affective, conative attitudes towards science as well as reservations and hopes towards science, and subjective norms regarding both science and society and informational behaviour (Schäfer et al., 2018). Other studies use different dimensions altogether and look at more specific constructs such as deference to scientific authority (Runge et al., 2018) or attitudes towards science policy making (Okamura, 2016). Further studies started with broadly defined dimensions, applied factor analysis to all their items and subsequently described new emerging dimensions such as ‘scepticism about science careers’ or ‘perceived independence of science and scientists’ (Castell et al., 2014). As a *third level*, the number of items representing a certain dimension also varies considerably. One example is the recurring dimension of ‘hopes and reservations regarding science’ where Besley (2018) uses three items while Schäfer et al. (2018) use seven. A more extreme example is the generic category of ‘attitudes towards science’, represented by six (Pullman et al., 2018) up to 19 items (Kawamoto et al., 2011). Finally, a *fourth level* pertains to the differences in variable measurement, both in wording and scale. This leads to cases where three different studies assess whether people agree that ‘science improves our lives’ by applying 4-, 5-, or 10-point scales, respectively, and using three (albeit slightly) different wordings (Nisbet and Markowitz, 2014; Pullman et al., 2018; Schäfer et al., 2018).

While there is considerable heterogeneity in variable selection, the differences are smaller than they appear. Some authors label very similar items with different dimensions or assign them to a broad category like ‘attitudes towards science’. Many prior analyses could have followed the already mentioned categorisation proposed by Schäfer et al. (2018): Pullman et al. (2018) would have covered hopes and reservations towards science as well as the subjective norm regarding informational behaviour. Besley (2018) included items that covered hopes and reservations as well as the cognitive dimension of attitudes towards science and technology. The problem is that segmentation analyses do not incentivise to improve conceptual clarity and comparability. In both examples, it would not have mattered to which theoretical dimension researchers would have assigned their items as they ended up analysing all items together.

I chose the categories by Schäfer et al. (2018) for illustrative purposes only. Future research should explore the most theoretically useful and practical common ground across established science communication surveys. This most certainly means that the set of variables has to be on the smaller side. Technical analyses in other fields have shown that some segment-solutions can be replicated by using fewer variables by focusing on the most powerful predictors (Chryst et al., 2018). Füchslin et al. (2018) replicated the solution by Schäfer et al. (2018) using 10 rather than 20 items. Efforts could also clarify further questions regarding the inclusion of sociodemographic and behavioural variables in the final framework or regarding the issue of items focusing on attitudes towards 'science and technology' versus 'science and research'.

Getting to a point of having identical items with identical measurements or even having new standardised scales seems a bit too optimistic at this point. If anything, it seems more plausible that established surveys would add new items than alter their existing item measurements. In their review of segmentations in climate change communication, Hine et al. (2014) point out that agreeing on common dimensions would be a step in the right direction.

I think that science communication, ideally, would identify a compact and widely applicable theoretical framework, maybe even find and promote a small but common set of standard items across nationally representative surveys. Ideally, such a framework would define a clear context such as 'public attitudes towards science and research' and provide a causal model describing relations between the included core constructs, similar to what we see in related fields like risk communication (Van der Linden, 2015). This would benefit all scholars interested in segmentation research, because it would not only help to design research, but would also incentivise surveys – new or even more established ones – to measure variables that cater to the proposed theoretical model. However, our field will only find the motivation to develop a framework if the goals of segmentations move away from serving specific communication purposes to investigating more systematic questions. One of the best ways to unify behind a more substantial research question seems to be collaborations between research teams – something which should be more easily achievable in a relatively small community like science communication.

2. We need methodological approaches that favour robust segment solutions

In line with these efforts towards a joint, or at least more explicit and ideally standardised, theoretical framework for variable selection, segmentation analyses in science communication should also aim to strengthen their methodological approach. Current analyses have employed almost all the most common statistical techniques for clustering data, ranging from distanced-based procedures like hierarchical (Runge et al., 2018) and k-means clustering (Ipsos MORI, 2013) to model-based procedures like latent class (Schäfer et al., 2018) and latent profile analysis (Pullman et al., 2018), sometimes with running a factor analysis in a first step (Kawamoto et al., 2011) and sometimes without (Guenther and Weingart, 2017). Other studies did not employ multivariate statistics at all and applied 'manual clustering' by defining which combinations of variable expressions would lead to which kind of segment (Cámara et al., 2018; Nisbet and Markowitz, 2014; Sweeney Research, 2011).

The variability in methods is related to the selection and measurement of variables. Researchers that had continuous variables often opted for k-means clustering while those with ordinal variables preferred latent class or latent profile analyses. Since this commentary focuses on segmentations based on representative survey data, all studies start with ordinal variable measurements. What leads to continuous variables is the calculation of indices that sometimes struggle with reliability coefficients (e.g. Besley, 2018; Okamura, 2016) or the application of factor analysis to reduce the large number of items. As a downside, these factor analyses often lead to novel dimensions that are hard to interpret as they consist of multiple items with differing and sometimes very low factor loadings. In addition, missing values tend to result from applying factor analyses to survey data (e.g. Kawamoto et al., 2011).

We do not see the same methodological variability within analyses, however, that we see across studies – leading to another challenge for our research field. Segmentation analyses are explorative procedures allowing the parallel application of multiple methods. Yet, almost none of the referenced analyses have compared their solutions across methods (cf. Table 1: Robustness checks). As a result, it remains unclear how robust these solutions are. This is less of a concern if researchers aim for practical segmentations. It would be less desirable, however, to build systematic approaches on solutions that are largely influenced by the segmentation method.

Future segmentations can advance in two regards: First, we should increase our understanding of segmentation methods when applied to a typical set of science communication variables. At this point, it seems reasonable to focus on procedures like latent class analysis that cater to ordinal variables. This is especially true if researchers in science communication can agree on a small set of items, as this would remove the temptation to reduce the number of variables through factor analysis. Second, researchers should begin to explore cluster solutions across multiple methods. This can go along with expanding the methodological repertoire by including procedures like random forest clustering (Giannella and Fischer, 2016), fuzzy clustering (Neunhoeffer and Teubner, 2018) or density-based clustering (Kassambara, 2017).

3. We need to focus on transparency and facilitate systematic efforts

All potential improvements in variable selection and methodological approaches are idle if authors do not facilitate the systematic continuation of their proposed segmentations. This goal ultimately hinges on two aspects: transparency and methodology.

Systematic segmentation efforts in science communication require *transparency* in reporting methods and results. Most of the studies outlined in Table 1 did not or only superficially report on details like the statistical software they used (i.e. name of software version or package), the application of survey weights, the treatment and potential imputation of missing values, the rationale for selection of cluster solutions and 'goodness of solutions' indicators (e.g. reporting dendrograms, Bayesian information criterion (BIC) values, discriminant analysis, etc.). For example, the series of UK segmentations has produced reports that present item- and segment-descriptions in large detail. But, when it comes to the methodological details, the report merely mentions that the authors ran a factor analysis and then administered a combination of hierarchical and k-means clustering (e.g. Ipsos MORI, 2011). Readers never get to see the factor loadings or what the dendrograms of the hierarchical solutions looked like.

Ideally, researchers should pick segmentation *methods* that facilitate transparent reporting and the continuation of prior efforts. For example, the combination of factor analysis and hierarchical clustering is an approach that does not lend itself to transparent reporting. Combining two exploratory methods entails many researcher degrees of freedom that authors simply cannot report on with a handful of statistics. Model-based approaches are inherently easier to report on in terms of choosing the final cluster solution and describing the goodness of the solution through widely used indicators like BIC and Akaike information criterion (AIC) values. They also offer solutions that build on regression models. This allows researchers to reuse established regression models and assign new cases to predefined segments – opening the door for continued and systematic application and testing of proposed solutions.

If authors used methods that facilitated transparent reporting and continued efforts, future research could take proposed segment solutions and apply them to their data for, say, another country or another time period. In climate change communication, the 'Six Americas' solution (Maibach et al., 2011) highlights this potential; researchers have applied it to other countries and periods (Morrison et al., 2013, 2018) and developed shorter scales (Chryst et al., 2018; Swim and Geiger, 2015). The continued efforts we see in science communication are by authors taking qualitative looks at specific clusters discovered in their previous studies (Kawamoto et al., 2013).

4. We can reap the benefits

Overall, segmentation analyses in science communication are becoming increasingly popular. Because they are not always necessarily working towards a goal of building a body of systematic knowledge, analyses currently feature a lot of variability in variable selection and measurement, application of methods and facilitation of continued efforts. Our field could take advantage of its high-quality data sets – many are publicly available (e.g. Eurobarometer or World Values Survey) or are likely to be made accessible by its owners – with large topical overlap and aim at systematic segmentation efforts, if we reduce and improve upon these variabilities. Luckily, dedicated future research can easily address all these challenges: improved application of methods and more transparent reporting do not require any new advances but good preparation and mid- to long-term planning. Working out a compact and widely applicable theoretical framework will be more challenging as it requires researchers to collaborate and agree to focus on more theory-driven systematic knowledge production. However, the investment would clearly be worth the effort in this case – finding a conceptually reasonable common ground among data sets could initiate a systematic application of segmentation analyses and result in truly relevant insights for our field.

Acknowledgements

I would like to thank the reviewers and, most of all, Professor Dr. Mike S. Schäfer for their valuable feedback on this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Note

1. An exception would be the reoccurrence of groups like the 'Sciencephiles' or the 'Disengaged/Disinterested', whereas the remaining groups seem to be more varied across countries and contexts.

ORCID iD

Tobias Füchslin https://orcid.org/0000-0002-2395-9674

References

Bauer MW (2009) The evolution of public understanding of science – Discourse and comparative evidence. *Science, Technology and Society* 14(2): 221–240.

Bauer MW and Falade BA (2014) Public understanding of science: Survey research around the world. In: Bucchi M and Trench B (eds) *Routledge Handbook of Public Communication of Science and Technology*, 3rd edn. London: Routledge, pp. 140–159.

Besley JC (2013) The state of public opinion research on attitudes and understanding of science and technology. *Bulletin of Science, Technology & Society* 33(1–2): 12–20.

Besley JC (2018) Audiences for science communication in the United States. *Environmental Communication* 12(8): 1005–1022.

Cámara M, van den Muñoz Eynde A and López Cerezo JA (2018) Attitudes towards science among Spanish citizens: The case of critical engagers. *Public Understanding of Science (Bristol, England)* 27(6): 690–707.

Castell S, Charlton A, Clemence M, Pettigrew N, Pope S, Quigley A, et al. (2014) *Public Attitudes to Science 2014: Main Report*. Retrieved from https://www.ipsos.com/ipsos-mori/en-uk/public-attitudes-science-2014

Chryst B, Marlon J, van der Linden S, Leiserowitz A, Maibach E and Roser-Renouf C(2018) Global warming's 'Six Americas Short Survey': Audience segmentation of climate change views using a four question instrument. *Environmental Communication* 12(8): 1109–1122.

Cormick C (2012) How do we gain the interest of people who are uninterested in science and technology? In: van Lente H, Coenen C, Fleischer T, Konrad K., Krabbenborg L., Milburn C., et al. (eds) *Little by Little: Expansions of Nanoscience and Emerging Technologies* (Studies of New and Emerging Technologies), vol. 3. Amsterdam: IOS Press, pp. 77–88.

Füchslin T, Schäfer MS and Metag J (2018) A short survey instrument to segment populations according to their attitudes toward science. Scale development, optimization and assessment. *Environmental Communication* 12(8): 1095–1108.

Füchslin T, Schäfer MS and Metag J (2019) Who wants to be a citizen scientist? Identifying the overall potential of citizen science and target segments in Switzerland. *Public Understanding of Science (Bristol, England)*.

Giannella E and Fischer CS (2016) An inductive typology of egocentric networks. *Social Networks* 47: 15–23.

Guenther L and Weingart P (2017) Promises and reservations towards science and technology among South African publics: A culture-sensitive approach. *Public Understanding of Science (Bristol, England)* 27: 47–58.

Guenther L, Weingart P and Meyer C (2018) 'Science is everywhere, but no one knows it': Assessing the cultural distance to science of rural South African publics. *Environmental Communication* 12(8): 1046–1061.

Hine DW, Reser JP, Morrison M, Phillips WJ, Nunn P and Cooksey R. (2014) Audience segmentation and climate change communication: Conceptual and methodological considerations. *Wiley Interdisciplinary Reviews: Climate Change* 5(4): 441–459.

Hurtado MC and Cerezo JAL (2012) Political dimensions of scientific culture: Highlights from the Ibero-American survey on the social perception of science and scientific culture. *Public Understanding of Science* 21(3): 369–384.

Ipsos MORI (2011) *Public Attitudes to Science 2011: Main Report*. Available at: https://www.ipsos.com/ipsos-mori/en-uk/public-attitudes-science-2011

Ipsos MORI (2013) *Community Attitudes Towards Emerging Technology Issues: Biotechnology*. Available at: https://archive.industry.gov.au/industry/IndustrySectors/nanotechnology/Publications/Documents/Emergingtechstudybio.pdf

Kassambara A. (2017). *Practical Guide to Cluster Analysis in R: Unsupervised Machine Learning* (Multivariate Analysis I), 1st edn. STHDA. Available at: http://www.sthda.com

Kawamoto S, Nakayama M and Saijo M (2011) A survey of scientific literacy to provide a foundation for designing science communication in Japan. *Public Understanding of Science (Bristol, England)* 22(6): 674–690.

Kawamoto S, Nakayama M and Saijo M (2013) Using a scientific literacy cluster to determine participant attitudes in scientific events in Japan, and potential applications to improving science communication. *Journal of Science Communication* 12(1): 1–12.

Maibach EW, Leiserowitz A, Roser-Renouf C and Mertz CK (2011) Identifying like-minded audiences for global warming public engagement campaigns: An audience segmentation analysis and tool development. *PLoS ONE* 6(3): e17571.

Metag J and Schäfer MS (2018) Audience segments in environmental and science communication: Recent findings and future perspectives. *Environmental Communication* 12(8): 995–1004.

MORI (2005) *Science in Society: Findings from Qualitative and Quantitative Research*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/260670/bis-05-1038-science-in-society-research.pdf

Morrison M, Duncan R, Sherley C and Parton K (2013) A comparison between attitudes to climate change in Australia and the United States. *Australasian Journal of Environmental Management* 20(2): 87–100.

Morrison M, Parton K and Hine DW (2018) Increasing belief but issue fatigue: Changes in Australian household climate change segments between 2011 and 2016. *PLoS ONE* 13(6): e0197988.

Neunhoeffer F and Teubner T (2018) Between enthusiasm and refusal: A cluster analysis on consumer types and attitudes towards peer-to-peer sharing. *Journal of Consumer Behaviour* 17(2): 221–236.

Nisbet M and Markowitz EM (2014) Understanding public opinion in debates over biomedical research: Looking beyond political partisanship to focus on beliefs about science and society. *PLoS ONE* 9(2): e88473.

Okamura K (2016) Dynamic development of public attitudes towards science policymaking. *Public Understanding of Science (Bristol, England)* 25(4): 465–479.

OST and Wellcome Trust (2000) *Science and the Public*. London: OST and Wellcome Trust.

Pullman A, Chen MY, Zou D, Hives BA and Liu Y (2018) Researching multiple publics through latent profile analysis: Similarities and differences in science and technology attitudes in China, Japan, South Korea and the United States. *Public Understanding of Science (Bristol, England)* 28: 130–145.

Research Councils UK (2008) *Public Attitudes to Science 2008: A Survey*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/260669/bis-08-p111-public-attitudes-to-science-2008-survey.pdf

Runge KK, Brossard D and Xenos MA (2018) Protective progressives to distrustful traditionalists: A post hoc segmentation method for science communication. *Environmental Communication* 21(1): 1–23.

Schäfer MS, Füchslin T, Metag J, Kristiansen S and Rauchfleisch A (2018) The different audiences of science communication: A segmentation analysis of the Swiss population's perceptions of science and their information and media use patterns. *Public Understanding of Science (Bristol, England)* 27(7): 836–856.

Scheufele DA (2018) Beyond the choir? The need to understand multiple publics for science. *Environmental Communication* 12(8): 1123–1126.

Sweeney Research (2011) *Community Interest and Engagement with Science and Technology in Victoria 2011*. Available at: http://science.sweeneyresearch.com.au/overview/

Swim JK and Geiger N (2015) From alarmed to dismissive of climate change: A single item assessment of individual differences in concern and issue involvement. *Environmental Communication* 11(4): 568–586.

Van der Linden S (2015) The social-psychological determinants of climate change risk perceptions: Towards a comprehensive model. *Journal of Environmental Psychology* 41: 112–124.

Author biography

Tobias Füchslin, MA, is a research and teaching associate at the division for science communication in the Department of Communication and Media Research (IKMZ), University of Zürich. His research focuses on attitudes towards science and research, scientific literacy and citizen science.

7.6 Füchslin et al. (2018)

A Short Survey Instrument to Segment Populations According to Their Attitudes Toward Science. Scale Development, Optimization and Assessment.

Füchslin, T., Schäfer, M. S., & Metag, J.

This article was originally published in:

Füchslin, T., Schäfer, M. S., & Metag, J. (2018). A Short Survey Instrument to Segment Populations According to Their Attitudes Toward Science. Scale Development, Optimization and Assessment. *Environmental Communication*, *12*(8), 1095–1108. https://doi.org/10.1080/17524032.2018.1461673

ENVIRONMENTAL COMMUNICATION
2018, VOL. 12, NO. 8, 1095–1108
https://doi.org/10.1080/17524032.2018.1461673

RESEARCH ARTICLE

A Short Survey Instrument to Segment Populations According to Their Attitudes Toward Science. Scale Development, Optimization and Assessment

Tobias Füchslin[a], Mike S. Schäfer[a] and Julia Metag[b]

[a]Department of Communication and Media Research, University of Zurich, Zürich, Switzerland; [b]Department of Communication and Media Research, University of Fribourg, Fribourg, Switzerland

ABSTRACT
Surveys play a key role in researching public perceptions of and attitudes toward science. Accordingly, there is a breadth of often-used survey instruments available which have also been adopted for segmentation analyses. Even though many of these segmentation solutions are similar in their aims, they often include a large numbers of variables, making it more difficult for other researchers to build on these solutions, as survey time is scarce. Therefore, we demonstrate how a large number of variables that were used for a comprehensive segmentation analysis can be reduced considerably without losing too much information. We develop and test a short survey instrument to segment populations according to their attitudes toward science. Results show that segmentation results can be replicated with over 90% accuracy by reducing the instrument from 20 to 10 variables. This reduction does not significantly affect the predictive power of segment attribution on three dependent variables, which suggests that many segmentation analyses could be similarly optimized, helping researchers save survey time and standardize segmentation analyses more.

ARTICLE HISTORY
Received 13 December 2017
Accepted 1 April 2018

KEYWORDS
Methods; audience segmentation; survey; attitudes toward science; science communication; Switzerland

1. Introduction: survey research, segmentation analyses and the need for short(er) survey instruments

Representative surveys on public perceptions of and attitudes toward science have a long tradition in many countries (for an overview, see Besley, 2013). Accordingly, a large number of survey instruments have been developed to assess, for example, people's "scientific literacy" (e.g. Kawamoto, Nakayama, & Saijo, 2013; Miller, 1983), their trust in science (e.g. Hendriks, Kienhues, & Bromme, 2015), their general reservations and beliefs about science (e.g. Bauer, 2016), or their preferences about the relation between science and society (e.g. European Commission, 2013; National Science Board, 2018).

Some of these instruments refer to clearly established concepts that have a history of extensive scholarly debates about different theoretical approaches, the adequate measurements, their validity, their shortcomings, and their potential improvements. This is true, for example, for measures of scientific literacy (cf. National Academies of Sciences, Engineering, and Medicine, 2016; Pardo & Calvo, 2004), and for measures of trust (cf. Hendriks, Kienhues, & Bromme, 2016; Schäfer, 2016). Other established measurements do not stem from such concise scholarly analysis and conceptual work. For example,

CONTACT Tobias Füchslin t.fuechslin@ikmz.uzh.ch Department of Communication and Media Research, University of Zurich, Andreasstrasse 15, CH-8050 Zürich, Switzerland
Supplemental data for this article can be accessed at https://doi.org/10.1080/17524032.2018.1461673

measurements of the relation between science and the public that are often used in surveys (e.g. European Commission, 2013; Wissenschaft Im Dialog, 2015) refer to a much broader scholarly debate about this relation, ideas of a potential participation of citizens, and the societal legitimation of science (see, e.g. the debates in Bucchi & Trench, 2016; Irwin & Wynne, 2003). In other words, they relate to general topical themes in the literature rather than dedicated conceptual work.

The breadth of available survey instruments is a clear positive, as it allows for the detailed analysis of science-related perceptions and attitudes across varying research interests and theoretical perspectives. Many of these measurements are widely used, e.g. in the international Eurobarometer surveys (European Commission, 2013) or in the Science and Engineering Indicators in the United States (National Science Board, 2018).

In addition, such perceptions and attitudes, captured via representative surveys, are often used in subsequent analyses, for example in segmentation analyses. Segmentation analyses "divide the general public into relatively homogeneous, mutually exclusive subgroupings" (Hine et al., 2014, p. 442), most often using quantitative, representative survey analyses with probability samples as the "gold standard" (Hine et al., 2014, p. 452). They have proved to be useful in many fields – such as social marketing (Yankelovich & Meer, 2006), environmental communication (Hine et al., 2014), health communication (Maibach, Roser-Renouf, & Leiserowitz, 2008), or political science (Sosnik, Fournier, & Dowd, 2007) – and have also been introduced in science communication (Guenther & Weingart, 2017; Kawamoto et al., 2013; Schäfer, Füchslin, Metag, Kristiansen, & Rauchfleisch, 2018).

These studies differ somewhat in the goals they ultimately pursue when applying the results of their segmentations – e.g. enhancing public communication of scientific results (e.g. State Government of Victoria, 2011), tracking the development of audience groups over time (e.g. Department for Business, Innovation & Skills, 2011; 2014), discovering cross-national differences (e.g. Liu, Tang, & Bauer, 2012; Mejlgaard & Stares, 2012), or building a basis for message design through additional analysis of communication channels (Metag, Füchslin, & Schäfer, 2017), or identifying interesting sub-populations for further research (e.g. Burns & Medvecky, 2018). But the aim of the segmentations themselves in these studies is usually very similar: They aim to distinguish groups among populations which are homogenous with regard to relevant characteristics – mostly with regard to "psychographic" variables such as perceptions and attitudes toward a specific issue.

Segmentation studies, particularly if they combine segmentation with an additional analytical step, can struggle with the available breadth of science-related survey instruments, however. Based on a long tradition of survey research assessing science-related attitudes, a large number of respective variables has been used, and no commonly agreed upon set of variables to assess attitudes toward science exists (Besley, 2013). This is associated with two main problems for science-related segmentation research:

- First, identifying the relevant variables for segmentation can be a challenge. Many segmentation studies do not rely on specified theoretical models and use an "atheoretical whatever-works approach" (Hine et al., 2014, p. 447) instead. Others base their segmentation analyses on several concepts, including, for example, scientific literacy as well as reservations and beliefs and interest regarding science (Liu et al., 2012). As a result, both kinds of segmentation studies include a large number of variables into their analyses (Department for Business, Innovation & Skills, 2011; Kawamoto et al., 2013). But survey time is often scarce, and therefore, scholars can be faced with a tradeoff between breadth and efficiency, i.e. between being "concise and informative" (Swim & Geiger, 2017, p. 568).
- Second, the results of different segmentation studies are sometimes hard to compare. While the respective studies might use similar names for the segments they eventually identified, these are often based on different survey items (such as Leiserowitz, Maibach, Roser-Renouf, & Smith, 2010; Metag et al., 2017). If one research group intended to build on another's segmentation, they would have to include the same high number of variables, which conflicts with the scarcity of survey time.

As a result, science-related segmentation analyses consist of many one-off segment solutions that are based on different and broad sets of variables which cannot be compared or easily reproduced without a large commitment of resources. We see two solutions for these problems:

- On the one hand, researchers could try to eliminate the problem through "theory-driven optimization" of their analyses, identifying the most relevant theoretical concepts in the field and developing adequate and valid measurements. This would certainly be a worthwhile endeavor. But many different survey items are already available, and many of them are embedded in longitudinal surveys (e.g. Eurobarometer and Science & Engineering Indicator surveys), which provide researchers with comparable data over longer time-spans, making it difficult to revise these surveys following a strict conceptual principle deductively. Still however, if researchers in the field would agree on a core set of concepts, comparability across studies would be guaranteed and survey time could then be optimized.
- On the other hand, researchers have tried to remedy the outlined problems through "statistics-driven optimization" (e.g. Swim & Geiger, 2017) on a case-by-case basis. Larger studies could then provide initial segmentation solutions whose measurement can subsequently be made more efficient (i.e. "shorter") and therefore more easily adopted by future studies.

Researchers using segmentation analyses in fields like climate change communication have already employed the second approach. They have made efforts recently to develop shorter survey instruments that allow researchers to establish population segmentation with acceptable levels of accuracy, yet using less survey time and increasing the chance to have comparable data sets and results. Maibach, Leiserowitz, Roser-Renouf, and Mertz (2011), in a study that inspired our analysis, introduced and tested a shorter, 15-item survey tool to assess the segmentation of the US populations according to their attitudes about climate change. Swim and Geiger (2017) proposed a seemingly radical approach, a "one-item scale," for the same topic, describing the segments found in earlier studies to respondents and asking them then to place themselves in one of them. Both studies were able to show that survey instruments could be significantly shortened without losing much of their analytical accuracy. Maibach et al.'s 15-item instrument, for example, could reattribute 83.8% of all cases correctly compared to the results of the "Global Warming's Six Americas" study. Swim and Geiger's one-item instrument also proved to be highly correlated with the original 36-item instrument, but showed significant differences in segment attributions for three of the six groups.

Since many national surveys on public attitudes toward science exist, are unlikely to unify their concepts and measurements, and are used for segmentation analyses, we set out to follow the second, statistics-driven, approach as well. We propose a short survey instrument and assess its accuracy. Therefore, we firstly ask:

> RQ1: How do shorter survey instruments affect segment attribution accuracy in the case of perceptions of and attitudes towards science?

In addition, we assess the predictive power of segment affiliation with regard to five selected behavioral variables – science-related media use regarding television, newspapers and magazines, and online sources; people's willingness to engage politically on science-related issues; and their frequency of talking about science and research with friends and acquaintances – and the changes of this power depending on the scope of the survey tool.

> RQ2.1: What is the predictive power of segment affiliation regarding these behavioral variables?

> RQ2.2: How is this predictive power affected by the shorter survey instruments?

Afterwards, we discuss how future studies can adopt our short survey instrument and, more importantly, how similar procedures could also be used by other researchers to make segmentation analyses in other contexts more efficient and accessible.

2. The reference study: identifying the different audiences of science communication in Switzerland

Our analysis relies on a segmentation study from Switzerland, which assessed the Swiss' perceptions of and attitudes toward science as well as their science-related patterns of information and media use (Schäfer et al., 2018). The study's design, its measurements, and findings have to be shortly introduced before we can develop a short survey tool based on its data.

2.1. Data

The data stem from a representative, national survey – the "Science Barometer Switzerland" (www.wissenschaftsbarometer.ch) – conducted in 2016. Based on public telephone listings (90% landlines, 10% mobile), households were randomly selected, household members chosen according to sex and age quotas, and interviewed using computer assisted telephone interviews (CATI). One thousand and fifty-one respondents participated (651 from the German-, 200 from the French-, and 200 from the Italian-speaking parts of the country). The final sample was weighted regarding region, gender, age, education, occupation, and household size.

2.2. Measurements

Faced with the breadth of variables in nationally representative surveys, the reference study covers a broad range of well-established measurements of peoples' perceptions of and attitudes toward science (cf. supplementary material). This approach mirrors previous segmentations (Department for Business, Innovation & Skills, 2014; Kawamoto et al., 2013) regarding science. Firstly, cognitive, affective, and conative aspects of attitudes toward science were assessed:

- To capture the *cognitive aspect*, respondents' knowledge about science was measured, using a quiz format (Kawamoto et al., 2013; Miller, 1983; Miller & Pardo, 2000).[1] In addition, we asked for respondents' interest in science (e.g. BBVA foundation, 2011; Department for Business, Innovation & Skills, 2014; European Commission, 2010).
- The *affective aspect* was assessed by asking respondents for their trust in science (Lee, Scheufele, & Lewenstein, 2005), and for their assessment of whether they think science plays an important role in their lives.
- The *conative aspect* was captured by asking whether respondents search for information about science actively, and whether they would like to be personally involved in a research project once (Wissenschaft Im Dialog, 2015).

Secondly, respondents' "reservations and beliefs" with regard to science were assessed through a set of questions that have been used in many international surveys before (e.g. European Commission, 2010; National Science Board, 2018). "Beliefs" capture the hopes and positive aspects people associate with science and scientific developments. "Reservations" encompass to what extent they think that science has limitations or that science and research can also have negative consequences. The Science Barometer Switzerland used an abbreviated variant of the version developed by Prpić (2011).

Thirdly, respondents' attitudinal preferences (i.e. subjective norms) with regard to science and science communication were assessed. Questions from different surveys were combined which asked respondents about their preferred relation of science and society (Besley, 2013; European Commission, 2010; Nisbet et al., 2002, p. 591; Wissenschaft Im Dialog, 2015). In contrast to the reservations and beliefs, this relation tackles the different ways science influences other systems of the society, such as politics or the public sphere, and is similarly influenced by or dependent on these systems, e.g. whether they think science should be funded even if it had no immediate use, whether it should be publicly funded, whether science should influence politics, whether scientists should inform the public about their results, etc. Furthermore, people's informational norms with regard to science were assessed (Kahlor, Dunwoody, Griffin, & Neuwirth, 2006), i.e. whether they think that it is important to be informed about science and research.

In addition, we measured a number of non-attitudinal variables that were not used to reconstruct segments of the Swiss population but to describe them in a second step. They include sociodemographic characteristics (age, sex and education (Besley, 2013; Nisbet et al., 2002; Roten, 2004), religiosity (OST & The Wellcome Trust, 2001), and political orientation (cf. Nisbet et al., 2002)), as well as reports of media and information use behavior with regard to science.

2.3. Results

Twenty variables capturing the Swiss populations' perceptions of and attitudes toward science were used in latent class analysis.[2] BIC values showed two- or three-cluster solutions to be unfavorable and all other solutions were on similar levels. As the four-cluster solution offered the clearest interpretation, it was used for further analysis and can be briefly summarized as follows (cf. Schäfer et al., 2018):

1. The "Sciencephiles" ($n = 292$; 27.8%) include people with high interest in, high knowledge of, and very positive attitudes and beliefs toward science. They think that science plays an important role in their lives and are highly supportive of science. Regarding the promises of science, they are the most hopeful and least critical of all segments.
2. The "Critically Interested" ($n = 181$; 17.2%) match the "Sciencephiles" in their knowledge of, attitudes toward, and support of science. The main difference is that they trust science considerably less, and have stronger reservations regarding science's promises. For example, they clearly favor research constraints and think that humanity relies too heavily on science in general.
3. The "Passive Supporters" ($n = 437$, 41.5%) are the largest group. Their interest, attitudes, and trust regarding science are moderate. While not as strong as the former two groups, however, they are still supportive of science. Overall, they share some hopes and reservations, again on moderate levels. For example, they think science improves our lives, but also that scientific research should have clear constraints.
4. The "Disengaged" ($n = 141$; 13.4%), the smallest segment, have the lowest, albeit still moderate support of science. They think, however, that science does not play an important role in their lives, and have the lowest knowledge of, interest in, and trust in science. Their hopes and reservations regarding science are similar to the "Critically Interested," but on a slightly less pronounced level.

3. Developing and testing a short survey instrument: results

The following analysis aims to develop a shorter survey instrument as an alternative to the 20-item version used in the reference study, and to test how much its accuracy decreases compared to the full version.

3.1. Construction and comparison of short survey instruments

In order to develop a shorter scale for identifying attitude segments, we first assess the predictive power of each of the 20 items used and, second, evaluate for each of the shortened instruments how many of the original cases were correctly attributed to their original segment.

The four-cluster solution of our segmentation analysis can be fully described by a linear combination of the 20 attitudinal items used in the reference study. Based on this survey instrument, researchers can calculate the likelihood of cases to belong to one of the four segments. We provide the SPSS syntax containing the equation to replicate our four-cluster solution in the supplemetary material.

It is also possible to describe the solution with a linear equation based on a subset of items. However, a shorter survey instrument reduces attribution accuracy, albeit to different degrees depending on the predictive power of the different items. Regarding RQ1, we calculated equations describing our four-segment solution, first based on 20 items, then on 19, 18, and so on, down to one item. These survey instruments were constructed according to the items' predictive power for segment attribution (see Table 1). Accordingly, the one-item instrument is based on the best predictor (1. "Science and research play an important role in my life"), the two-variable instrument on the best two predictors (+2. "I specifically search for information about science and research"), and so forth.

We applied each equation to the cases in our original data set to compare how accurate the predictions based on shorter instruments are in comparison to the original four-segment solution. For each instrument, Figure 1 shows how many of the original cases were correctly attributed to their original segment.

Using the 10 best predictors, results in 92.1% of all cases still being attributed in accordance with the original 20-item solution. Instruments based on the best 12 or more variables produce more than 95% correct attributions. In turn, accuracy drops more quickly for instruments using fewer than the best 10 predictors. As expected, the instrument based on the sole best predictor yields the lowest accuracy with 59.5%. Thus, we argue that, based on statistics alone, a survey instrument incorporating only 10 out of the original 20 items can be used to reproduce the attitudes segments reliably.

As an additional benefit, the 10-item solution also covers all of the main attitudinal categories such as cognitive, affective, and conative attitudes or people's "reservations and beliefs" with at least one item. Interestingly, however, scientific literacy, one of the best conceptualized instruments in science communication, was not found to be one of the 10 most important predictors.

Table 1. Segmentation variables of reference study ranked according to their predictive power for segment attribution.

Segmentation items	R^2	
1. "Science and research play an important role in my life"	0.4679	Proposed 10-item solution
2. "I specifically search for information about science and research"	0.403	
3. "It is important to be informed about science and research"	0.3498	
4. "How interested are you in science and research?"	0.3123	
5. "Scientific research should be publicly funded"	0.3041	
6. "Science and research make our lives better"	0.3036	
7. "I would like to partake in scientific research once"	0.3030	
8. "How high is your trust in science in general?"	0.2906	
9. "Science should have no limits to what it is able to investigate"	0.2752	
10. "Science and technology can sort out any problem"	0.2445	
11. "Scientific research is necessary even if there is no immediate application"	0.2314	
12. "Science will eventually provide a full picture of how nature and the universe works"	0.2006	
13. "Political decisions should be based on scientific findings"	0.1949	
14. "Scientists should inform the public about their work"	0.1820	
15. "The benefits of science are greater than any harmful effects it may have"	0.1400	
16. Index: Scientific Literacy	0.1238	
17. "People like me should be involved in decisions about the topics scientists research"	0.0577	
18. "Scientists should listen more to what regular people think"	0.0173	
19. "We rely too heavily on science"	0.0114	
20. "Science makes our ways of life change too fast"	0.0087	

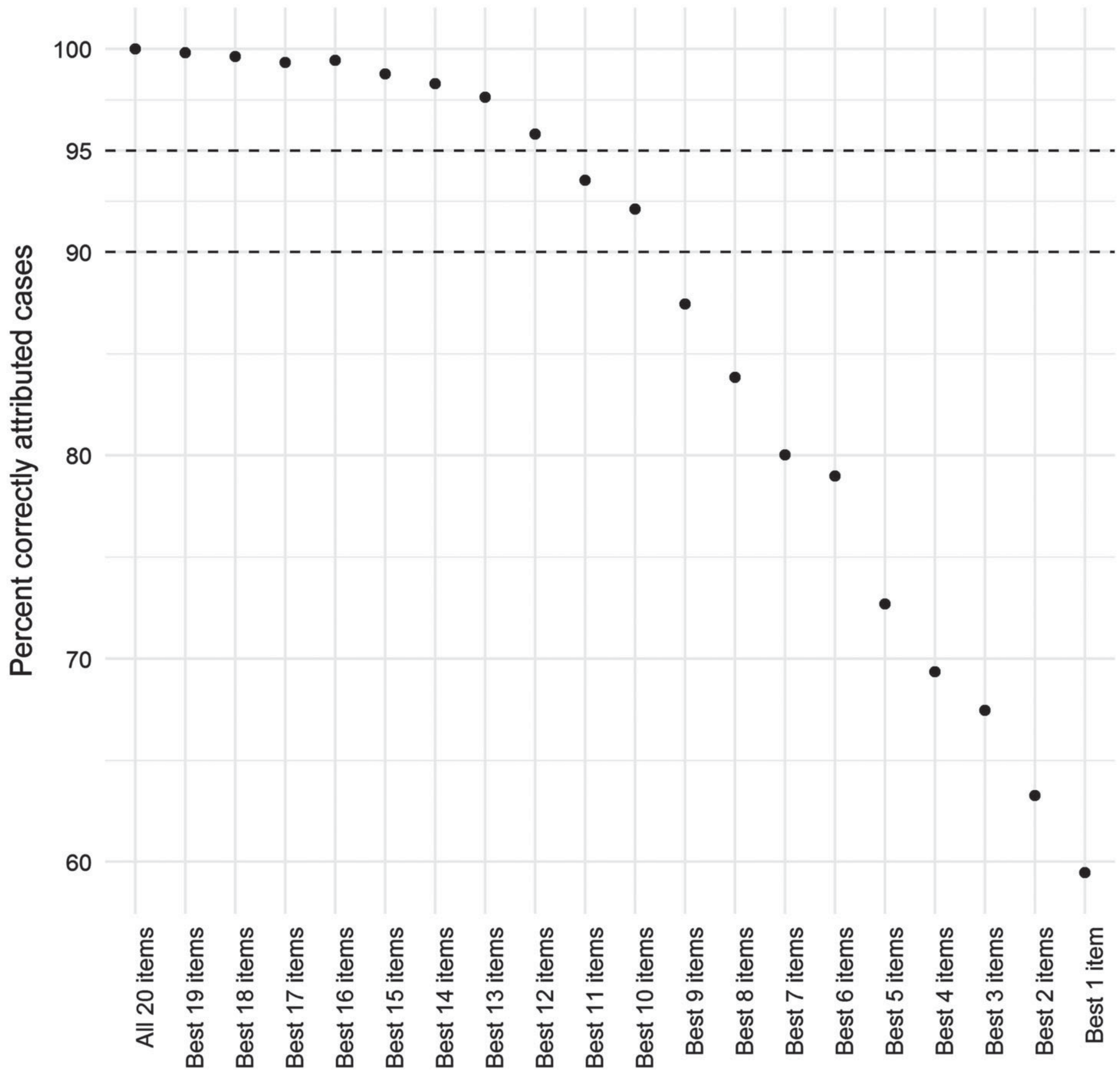


Figure 1. Percentage of correctly assigned cases based on different survey instrument lengths (20-item instrument as reference).

3.2. Regression-based validation of the short survey instruments

Segmentation analyses reconstruct divisions between groups of people that are connected to other factors – to sociodemographic profiles (e.g. Kawamoto et al., 2013), to peoples' general values (e.g. Roser-Renouf, Maibach, Leiserowitz, Feinberg, & Rosenthal, 2016), to behavioral intentions (e.g. Maibach et al., 2011), or information use (e.g. Metag et al., 2017). Similarly, our previous analyses of the Swiss case have shown that the four identified segments differ not only in their attitudes toward science, but also with regard to a broad range of media and information variables and sociodemographics (cf. Schäfer et al., 2018). These differences, however, were only assessed on a bivariate level.

To further assess the short survey instruments proposed here, we used multivariate models to evaluate the predictive power of segment affiliation regarding such topically related dependent variables (RQ2.1), and to subsequently assess how this predictive power is affected by the shortening of the survey instrument item by item (RQ2.2).

To answer RQ2.1, we tested the influence of segment membership on five separate dependent variables (cf. Tables 2 and 3). The first three models focus on people's contact with science and research through the three most relevant science media sources in Switzerland: Swiss public television (*1 = "never" … 5 = "very often"; m = 2.86, sd = 1.2*), daily and weekly newspapers and magazines (*1 = "never" … 5 = "very often"; m = 3.28, sd = 1.22*), and online media (*using an index of seven online sources; 1 = "never" … 5 = "very often"; m = 2.06, sd = 0.81*).[3] For the next two models, we chose two behavioral variables: people's willingness to vote on science-related issues ("When the issue is

Table 2. Linear regression models with effects on peoples' overall contact with science and research through national television, daily and weekly newspapers and magazines, and online media.

	Model 1: National television contact			Model 2: Daily and weekly newspapers and magazines contact			Model 3: Online media contact		
IVs	Std. beta	Std. CI	*p*	Std. beta	Std. CI	*p*	Std. beta	Std. CI	*p*
(Intercept)			<.001			<.001			<.001
Gender (*Female*)	0.04	−0.02 to 0.10	.215	0.01	−0.05 to 0.07	.720	−0.06	−0.12 to −0.00	.034
Age	0.16	0.10 to 0.23	<.001	0.19	0.13 to 0.26	<.001	−0.35	−0.41 to −0.29	<.001
Education (*Primary*)									
Secondary	0.15	0.04 to 0.25	.007	0.05	−0.05 to 0.15	.344	0.09	−0.00 to 0.18	.061
Tertiary	0.11	−0.00 to 0.22	.060	0.08	−0.02 to 0.19	.129	0.14	0.04 to 0.24	.005
Religiosity	0.08	0.02 to 0.15	.011	0.02	−0.04 to 0.08	.518	−0.04	−0.10 to 0.02	.156
Political Orientation	−0.03	−0.10 to 0.03	.281	−0.07	−0.13 to −0.01	.027	0.00	−0.05 to 0.06	.867
Segment ("Passive Supporters")									
"Sciencephiles"	0.04	−0.03 to 0.11	.234	0.14	0.07 to 0.21	<.001	0.28	0.22 to 0.34	<.001
"Critically Interested"	−0.05	−0.12 to 0.02	.136	0.04	−0.02 to 0.11	.210	0.10	0.04 to 0.16	<.001
"Disengaged"	−0.04	−0.11 to 0.02	.177	−0.17	−0.23 to −0.10	<.001	−0.17	−0.22 to −0.11	<.001
Observations		971			969			958	
Adj. R^2		.052			.113			.266	

science-related, I always participate in popular votes"; *1 = "do not agree at all" … 5 = "agree strongly"; m = 4.03, sd = 1.23*) and people's frequency of talking about science with their friends *("How often do you talk about science and research with friends and acquaintances"; 1 = "never" … 5 = "very often"; m = 2.47, sd = 1.08*).

As our independent variables, we chose a basic set of demographics and value predispositions established in science communication research (e.g. Anderson, Brossard, Scheufele, Xenos, & Ladwig, 2014; Shih, Scheufele, & Brossard, 2012): age (*m = 46.33, sd = 17.9*), gender (*50.8% female*), highest education level (*43.3% tertiary education, 44.9% secondary education*), political orientation (*1 = "far left" … 7 = "far right," m = 3.64, sd = 1.28*), and religiosity (*1 = "not religious at all" … 5 = "highly religious," m = 2.72, sd = 1.25*). Additionally, we included people's attribution to one of the four segments (*reference category = "Passive Supporters"*) based on the original solution which included 20 items.[4]

- Model 1 (*adj.* $R^2 = 5.2\%$) shows positive correlations of age, education and religiosity with people's contact with science and research through Swiss public television. The three segment variables do not show any significant[5] relation. Overall, the independent variables are only able to explain about 5% of the dependent variable's variance.

Table 3. Linear regression models with effects on peoples' willingness to participate in public votes on science-related issues and people's frequency of talking to friends and acquaintances about science and research.

	Model 4: Willingness to vote on science-related issues			Model 5: Talking about science and research		
IVs	Std. beta	Std. CI	*p*	Std. beta	Std. CI	*p*
(Intercept)			<.001			<.001
Gender (*Female*)	−0.02	−0.09 to 0.04	.461	0.00	−0.05 to 0.06	.925
Age	0.09	0.03 to 0.16	.004	−0.09	−0.15 to −0.03	.002
Education (*Primary*)						
Secondary	0.14	0.01 to 0.28	.041	0.09	−0.00 to 0.19	.056
Tertiary	0.19	0.05 to 0.33	.009	0.11	0.01 to 0.20	.036
Religiosity	−0.04	−0.11 to 0.02	.226	−0.02	−0.08 to 0.04	.489
Political Orientation	0.01	−0.06 to 0.07	.806	−0.02	−0.07 to 0.04	.599
Segment ("Passive Supporters")						
"Sciencephiles"	0.20	0.12 to 0.27	<.001	0.31	0.24 to 0.37	<.001
"Critically Interested"	0.12	0.05 to 0.19	.001	0.21	0.15 to 0.27	<.001
"Disengaged"	−0.26	−0.33 to −0.20	<.001	−0.26	−0.32 to −0.21	<.001
Observations		842			975	
Adj. R^2		.174			.248	

- Model 2 (*adj.* $R^2 = 11.3\%$) displays a significant relations of age (positive) and political orientation (negative) with people's contact with science and research through daily and weekly newspapers and magazines. This time, segment variables prove to be some of the strongest predictors: Being a "Sciencephiles" has a significantly positive correlation with print media contact, while being a "Disengaged" is negatively related.
- Model 3 (*adj.* $R^2 = 26.6\%$) shows that younger respondents, men and respondents with higher education come significantly more often into contact with science and research online. All segment variables turn out to be significant predictors for respondents' use of online media. Attribution to the "Disengaged" segment correlates negatively with the use of these media, while belonging to the "Sciencephiles" and the "Critically Interested" is positively correlated.
- Model 4 (*adj.* $R^2 = 17.4\%$) depicts positive correlations of education and age with people's willingness to participate in public votes on science-related issues. Furthermore, all segments prove to be significantly linked to science-related voting decisions: Belonging to the "Sciencephiles" or "Critically Interested" has a positive association, while attribution to the "Disengaged" has a negative one.
- Model 5 (*adj.* $R^2 = 24.8\%$) shows that younger and more educated people are significantly more likely to talk about science and research with friends and acquaintances. The three strongest predictors, however, are affiliations to the three segments. Just as in model 4, attribution to the "Sciencephiles" and "Critically Interested" is positively related and attribution to the "Disengaged" negatively.

To answer RQ2.2, i.e. to assess how this predictive power is affected by shorter survey variants, we compared how the five explanatory models change when replacing the full segment attributions based on 20 items with those based on the shorter survey instruments, going from 19, 18, 17 items down to segment attributions based on just one item. Figure 2 shows the percentage of adjusted explained variance the segment attribution variable contributed to predicting one of the five dependent variables (models 1–5).

- For model 1, the segmentation variables barely offer any added explained variance. It ranges around 0.5% across all 20 solutions. This is not surprising, as the full model previously showed that they do not have any significant influence on people's contact with science through television.
- Results across 20 segment solutions are more telling for model 2, where the gained *R*-squared remains stable around 5% (+/− 0.5%) from the full, 20-item instrument down to the seven best predictors. After that, it falls as low as 2.2% at the two-item solution. Despite these larger fluctuations for the smaller instruments, the influence of attribution to the "Sciencephiles" and "Disengaged" shrinks but remains significant in all instruments. Only at the one-item instrument, attribution to the "Critically Interested" turns statistically significant.
- For model 3, the gained *R*-squared remains even more stable than in the previous two models, accounting for approximately 11.2% (+/− 0.8%) from the 20-item down to the 2-item solution. In line with this observation, the segment indicators remain significant influences throughout all 20 solutions.
- For model 4, the explained variance added by the segmentation variables ranges between 14.8% (7-item scale) and 8.1% (2-item scale). From 20-item to the 8-item instrument, the explanatory power remains constant around 12.5% (+/− 0.7%). In all cases, the segmentation variables do add a significant gain in explained variance to the model. The strong correlation of attribution to the "Sciencephiles" and the "Disengaged" remains significant across all versions. The link to belonging to the "Critically Interested" only drops below statistical significance for the scales based on two to eight items.
- For model 5, segment variables add around 20.2% (+/− 0.8%) of explained variance to the models based on solutions with 20 down to five items. The smallest four solutions display a more random gain of *R*-squared, ranging from 22.4% (four-item solution) to 14.8% (one-item solution). The three segment variables, however, remain their significant correlation with people's frequency

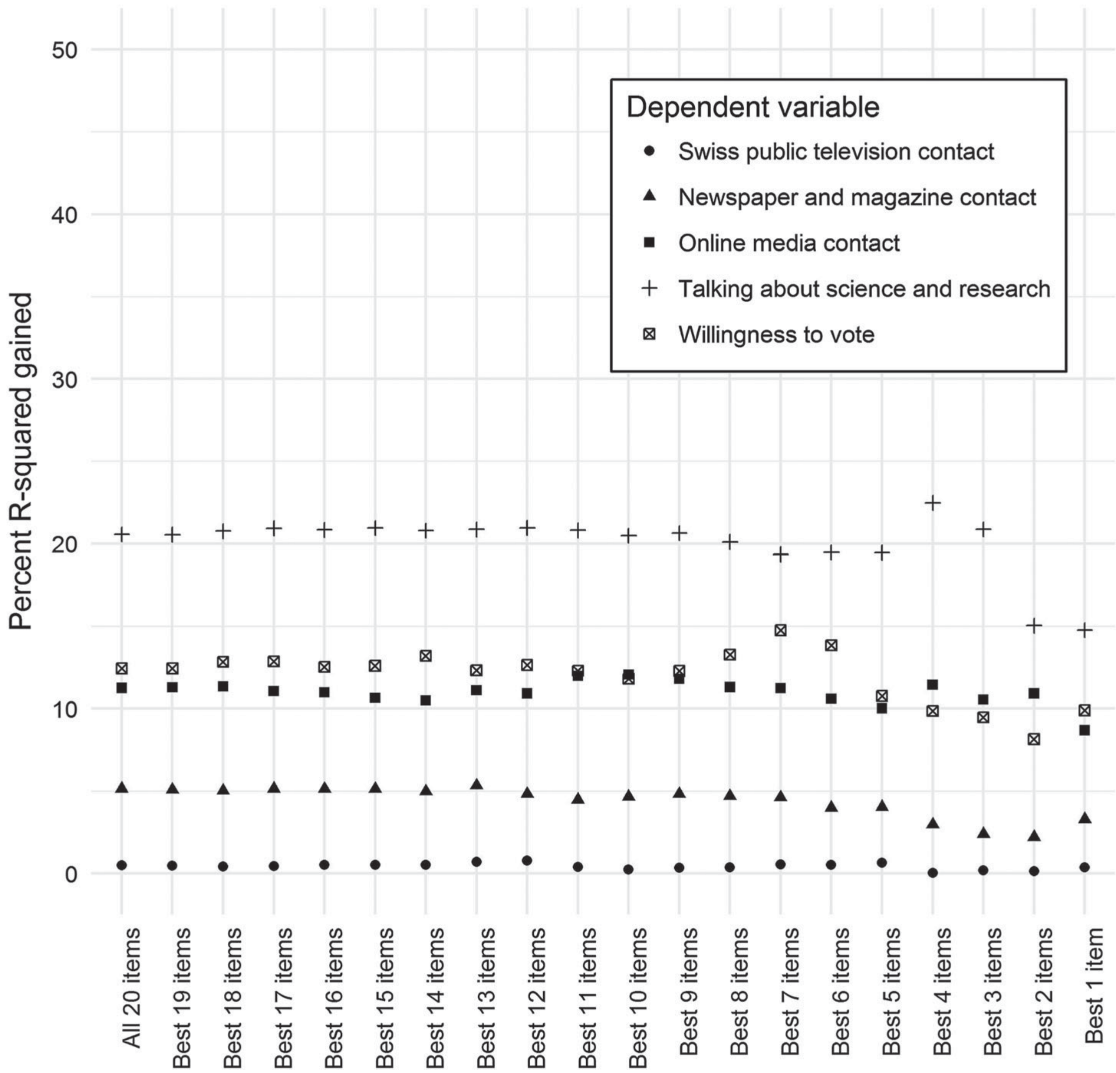


Figure 2. Percentage of adjusted explained variance added to the media contact and behavior models by including segment variables based on different survey instrument lengths.

of talking about science with friends across almost all 20 models. Only at the last model, based on the one-item solution, belonging to the "Critically Interested" loses its significant correlation.

Overall, these results show that the statistical models produce stable results even when the original 20 segmentation variables are replaced by solutions with fewer items. In all five models, the explained variance gained by the segment variables remains stable down to the model based on eight items. Results fluctuate more strongly for the smaller solutions. Such consistent results make sense, as at least 80% of cases receive an identical attribution. The more incorrect segment attributions a short survey instrument contains, the more it is up to chance in which segment an individual ends up, which randomly distorts all further analyses.

4. Discussion and conclusion

Survey research on public perceptions of and attitudes toward science uses a breadth of science-related survey instruments. Many segmentation analyses, even though many of them share similar goals, have therefore used a high number of variables to identify segments of different populations which are homogeneous in their attitudes toward science. This makes it difficult for subsequent studies to build on these solutions, as they would have to use similarly extensive sets of variables to reconstruct these segmentations. While it would be desirable that science communication scholars agree on a smaller number of theoretical concepts in the first place (cf. Bauer, 2012), we proposed a more pragmatic statistical optimization, and assessed to what extent shorter survey instruments would allow researchers to establish population segmentation with acceptable levels of accuracy while devoting less survey time to capture the respective items. Using survey data from Switzerland, we analyzed how shorter survey instruments affect segment attribution accuracy, and in how far the predictive power of segment affiliation is affected by shorter survey instruments.

Results have shown two robust findings: First, removing the items with the weakest influence on segmentation only marginally affected the accuracy of the attribution of respondents to attitudinal segments, up to a certain point. With half the number of original items – 10 instead of 20 – we were still able to assign more than 90% of all respondents correctly to the same segments derived from the 20-item solution. Given that a larger drop-off in accuracy occurred after the 10-item version, we recommend that this 10-item version should be used in future studies. Not only is this solution statistically accurate, it also covers all the concepts included in the original solution: cognitive (one item), affective (two items), and conative (two items) attitudes; reservations and beliefs (three items); beliefs regarding the relationship between science and society (one item); and the informational norm (one item) (cf. Table 1 and supplementary material). Such future studies can employ the 10-item solution directly (cf. syntax in supplementary material) but would also be able to assess the accuracy of other, either longer and shorter versions of the original survey instrument based on our results.

Second, our results have also shown that segment affiliation can be a powerful behavioral predictor. Previous research already suggested this with regard to media and information use and other behavioral variables, and the reference study described above has indicated this as well. To assess the explanatory power of the shorter survey instruments, we provided additional regression analyses assessing the predictive power of belonging to a given segment on different media contact and behavioral variables while controlling for sociodemographic variables. Models for media contact with science – via television, newspapers and magazines, and online media – and of lifeworld behavior – voting in science-related referenda and talking to friends about science – demonstrated that segmentation attributions are some of the most powerful correlates.

Only for one of the five dependent variables, people's contact with science and research through Swiss public television, segment variables did not have any relevant correlations. The otherwise strong correlations reflect that the solution contains many key measurements such as conative attitudes for behavioral outcomes and cognitive attitudes for media consumption to predict different outcome variables.

Furthermore, we showed that the application of shorter prediction instrument leads to results similar to those obtained with the 20-item version, again up to a certain point. For all five dependent variables, incorporating a shorter scale for segment prediction does not skew the results in a meaningful way. In all cases, the 10-item solution recommended above had a predictive power similar to the 20-item solution (+/– 0.8%). When comparing the 10-item to the full 20-item solution, the three variables indicating respondents' attribution to the specific segments remained significantly correlated to all the five dependent behavioral variables we tested.

These results are encouraging for researchers aiming to build on established segmentation analyses and yet save survey time: respondents' segment affiliation with regard to attitudes toward science can be predicted well with a smaller set of items. In addition, there seems to be clear value in ascertaining group attribution, and it is worth doing so even when resources or survey time are limited. We provide our short survey instrument for other researchers; but more importantly, we hope that the general approach we have outlined in this article encourages future research to take advantage of this kind of evaluation when doing their own segmentation analyses, laying the groundwork for continued and comparative analyses.

It is important to highlight, again, that a statistics-driven optimization is not the only way of optimization. It would be even more valuable to the science communication community if scholars tried to conceptually identify the most relevant constructs (cf. Bauer, 2012). Such efforts should, on the one hand, also consider newer concepts such as "ordinary science intelligence" (Kahan, 2016), which extends the traditional measurement of scientific literacy (construct and process knowledge) by including quantitative reasoning and cognitive reflection abilities. On the other hand, they should revisit overlooked concepts from other disciplines such as people's "epistemic beliefs" (Chinn, Buckland, & Samarapungavan, 2011), which ascertain the way people belief knowledge to be structured (e.g. stable vs. tentative).

Nonetheless, our results and approach need further strengthening as well. Similar analyses using other datasets would be useful tests for the procedure proposed here, as would be additional tests of the predictive power of segment affiliation using other dependent variables or measuring similar dependent variables not only via one item, like we did for two of our three dependent variables (due to our own survey time constraints), with more elaborate measures. Importantly, testing short(er) survey instruments in other national contexts would be helpful. After all, Switzerland may be a peculiar case – a highly innovative country with excellent universities and a high degree of spending for tertiary education – and results in other countries may differ (cf. Guenther & Weingart, 2017 for South Africa; Kawamoto et al., 2013 for Japan).

Such additional tests would be worthwhile, however: while it is always recommendable to include as many of the original variables as possible in segmentation analyses, this will not always be feasible, or practical, in studies. Under these circumstances, being able to fall back on an alternative which is concise yet still informative would be helpful.

Notes

1. As this format has been criticized (e.g. Pardo & Calvo, 2002, 2004), the format was adapted to include questions about arts and humanities in addition to the (natural) sciences, to include both textbook and applied scientific knowledge, and to also include a question about the process of science. Easier and more difficult questions (according to the correct number of answers in previous surveys where available) were mixed. And the dichotomous "correct–false" answer format that is often used was switched to a format allowing respondents to indicate the level of certainty in their answers (Pardo & Calvo, 2004, 223f.). These changes were crosschecked both with a recoded, traditional "right"/"wrong" scale for all 11 questions and with a recoded version containing only those five questions which were taken verbatim from earlier studies.
2. We ran the analysis with LatentGold 5.1 (Vermunt & Magidson, 2016). Five thousand random sets of starting values were entered into the algorithm to ensure validity and robustness of each solution.
3. Each media source was measured via a single survey item. While we had a similar one-item variable available for overall "internet" contact with science, we took advantage of an additional question in which we asked respondents for their online use in more detail. We could build an online media index ($\alpha = 0.80$) consisting of the use of following sources to get in contact with science and research: online outlets of newspapers and magazines; online archives of television and radio channels; institutional websites (scientific, government, organizations); Facebook; blogs or message boards; Wikipedia; YouTube or similar video platforms.
4. Except for normal distribution of residuals in model one and four, all assumptions of linear regression were met in the other three models. Due to the large sample size, however, the linear models should be robust enough to overcome these slight distortions.
5. We use "significant" as $p < .05$.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Gebert Rüf Stiftung, Stiftung Mercator Schweiz, and the University of Zurich's Department of Communication and Media Research (IKMZ).

References

Anderson, A. A., Brossard, D., Scheufele, D. A., Xenos, M. A., & Ladwig, P. (2014). The "nasty effect:" online incivility and risk perceptions of emerging technologies. *Journal of Computer-Mediated Communication*, *19*(3), 373–387.

Bauer, M. W. (2012). Science culture and its indicators. In B. Schiele, M. Claessens, & S. Shi (Eds.), *Science communication in the world: Practices, theories and trends* (pp. 295–312). Dordrecht: Springer. doi:10.1007/978-94-007-4279-6_20

Bauer, M. W. (2016). *The culture of science indicators*. London: LSE.

BBVA Foundation. (2011). *International study on scientific culture: Understanding of science*. Bilbao: Author.

Besley, J. C. (2013). The state of public opinion research on attitudes and understanding of science and technology. *Bulletin of Science, Technology & Society*, *33*(1–2), 12–20.

Bucchi, M., & Trench, B. (Eds.). (2016). *The public communication of science: Volume III: Publics for science*. London: Routledge.

Burns, M., & Medvecky, F. (2018). The disengaged in science communication: How not to count audiences and publics. *Public Understanding of Science (Bristol, England)*, *27*(2), 118–130. doi:10.1177/0963662516678351

Chinn, C. A., Buckland, L. A., & Samarapungavan, A. (2011). Expanding the dimensions of epistemic cognition: Arguments from philosophy and psychology. *Educational Psychologist*, *46*(3), 141–167.

Department for Business, Innovation & Skills. (2011). *Public attitudes to science 2011: Main report*. London: Ipsos MORI.

Department for Business, Innovation & Skills. (2014). *Public attitudes to science 2014: Main report*. London: Ipsos MORI.

European Commission. (2010). *Special eurobarometer 340: Science and technology*. Brussels: Author.

European Commission. (2013). *Special eurobarometer 401: Responsible research and innovation (RRI), science and technology*. Brussels: Author.

Guenther, L., & Weingart, P. (2017). Promises and reservations towards science and technology among South African publics: A culture-sensitive approach. *Public Understanding of Science*, *27*(1), 47–58.

Hendriks, F., Kienhues, D., & Bromme, R. (2015). Measuring laypeople's trust in experts in a digital Age: The Muenster Epistemic Trustworthiness Inventory (METI). *Plos One*, *10*(10), 1–20. doi:10.1371/journal.pone.0139309

Hendriks, F., Kienhues, D., & Bromme, R. (2016). Trust in science and the science of trust. In B. Blöbaum (Ed.), *Trust and communication in a digitized world: Models and concepts of trust research* (pp. 143–159). Cham: Springer International. doi:10.1007/978-3-319-28059-2_8

Hine, D. W., Reser, J. P., Morrison, M., Phillips, W. J., Nunn, P., & Cooksey, R. (2014). Audience segmentation and climate change communication: Conceptual and methodological considerations. *Wiley Interdisciplinary Reviews: Climate Change*, *5*(4), 441–459.

Irwin, A., & Wynne, B. (2003). *Misunderstanding science? The public reconstruction of science and technology*. Cambridge, UK: Cambridge University Press.

Kahan, D. M. (2016). "Ordinary science intelligence": A science-comprehension measure for study of risk and science communication, with notes on evolution and climate change. *Journal of Risk Research*, *20*(8), 995–1016. doi:10.1080/13669877.2016.1148067

Kahlor, L., Dunwoody, S., Griffin, R. J., & Neuwirth, K. (2006). Seeking and processing information about impersonal risk. *Science Communication*, *28*(2), 163–194.

Kawamoto, S., Nakayama, M., & Saijo, M. (2013). A survey of scientific literacy to provide a foundation for designing science communication in Japan. *Public Understanding of Science*, *22*(6), 674–690.

Lee, C.-J., Scheufele, D. A., & Lewenstein, B. V. (2005). Public attitudes toward emerging technologies: Examining the interactive effects of cognitions and affect on public attitudes toward nanotechnology. *Science Communication*, *27*(2), 240–267.

Leiserowitz, A., Maibach, E., Roser-Renouf, C., & Smith, N. (2010). *Global warming's Six Americas*. New Haven, CT: Yale University and George Mason University.

Liu, X., Tang, S., & Bauer, M. (2012). Comparing the public understanding of science across China and Europe. In M. W. Bauer, R. Shukla, & N. Allum (Eds.), *The culture of science: How the public relates to science across the globe* (Vol. 15, pp. 139–157). New York, NY: Routledge.

Maibach, E. W., Leiserowitz, A., Roser-Renouf, C., & Mertz, C. K. (2011). Identifying like-minded audiences for global warming public engagement campaigns: An audience segmentation analysis and tool development. *Plos One*, *6*(3), e17571. doi:10.1371/journal.pone.0017571

Maibach, E. W., Roser-Renouf, C., & Leiserowitz, A. (2008). Communication and marketing as climate change–intervention assets: A public health perspective. *American Journal of Preventive Medicine*, *35*(5), 488–500.

Mejlgaard, N., & Stares, S. (2012). Validating survey measures of scientific citizenship. In M. W. Bauer, R. Shukla, & N. Allum (Eds.), *The culture of science: How the public relates to science across the globe* (Vol. 15, pp. 418–435). New York, NY: Routledge.

Metag, J., Füchslin, T., & Schäfer, M. S. (2017). Global warming's five Germanys: A typology of Germans' views on climate change and patterns of media use and information. *Public Understanding of Science*, *26*(4), 434–451.

Miller, J. D. (1983). Scientific literacy: A conceptual and empirical review. *Daedalus*, *112*(2), 29–48.

Miller, J. D., & Pardo, R. (2000). Civic scientific literacy and attitude to science and technology: A comparative analysis of the European Union, the United States, Japan, and Canada. In M. Dierkes & C. von Grote (Eds.), *Between understanding and trust. The public, science and technology* (pp. 81–130). Reading: Harwood Academic.

National Academies of Sciences, Engineering, and Medicine. (2016). *Science literacy: Concepts, contexts, and consequences*. Washington, DC: National Academies Press.
National Science Board. (2018). *Science and engineering indicators 2018: Science and technology: Public attitudes and understanding (Science and engineering indicators)*. Arlington, VA: National Science Foundation.
Nisbet, M. C., Scheufele, D. A., Shanahan, J., Moy, P., Brossard, D., & Lewenstein, B. V. (2002). Knowledge, reservations, or promise? A media effects model für public perceptions of science and technology. *Communication Research*, *29*(5), 584–608.
OST & the Wellcome Trust. (2001). Science and the public: A review of science communication and public attitudes toward science in Britain. *Public Understanding of Science*, *10*(3), 315–330.
Pardo, R., & Calvo, F. (2002). Attitudes toward science among the European public: A methodological analysis. *Public Understanding of Science*, *11*(2), 155–195.
Pardo, R., & Calvo, F. (2004). The cognitive dimension of public perceptions of science: methodological issues. *Public Understanding of Science*, *13*(3), 203–227.
Prpić, K. (2011). Science, the public, and social elites: How the general public, scientists, top politicians and managers perceive science. *Public Understanding of Science*, *20*(6), 733–750.
Roser-Renouf, C., Maibach, E., Leiserowitz, A., Feinberg, G., & Rosenthal, S. (2016). Faith, morality and the environment: Portraits of global warming's six Americas. *Online:* http://climatecommunication.yale.edu/publications/faith-morality-environment/
Roten, F. C. V. (2004). Gender differences in attitudes toward science in Switzerland. *Public Understanding of Science*, *13*(2), 191–199.
Schäfer, M. S. (2016). Mediated trust in science. Concept, measurement and perspectives for the "science of science communication." *JCOM*, *15*, C02.
Schäfer, M. S., Füchslin, T., Metag, J., Kristiansen, S., & Rauchfleisch, A. (2018). The different audiences of science communication: A segmentation analysis of the Swiss population's perceptions of science and their information and media use patterns. *Public Understanding of Science*. Advance online publication. doi:10.1177/0963662517752886
Shih, T.-J., Scheufele, D. A., & Brossard, D. (2012). Disagreement and value predispositions: Understanding public opinion about stem cell research. *International Journal of Public Opinion Research*, *25*(3), 357–367.
Sosnik, D. B., Fournier, R., & Dowd, M. J. (2007). *Applebee's America: How successful political, business, and religious leaders connect with the new American community*. New York, NY: Simon and Schuster.
State Government of Victoria. (2011). *Community interest and engagement with science and technology in Victoria 2011*. Retrieved from http://science.sweeneyresearch.com.au/
Swim, J. K., & Geiger, N. (2017). From alarmed to dismissive of climate change: A single item assessment of individual differences in concern and issue involvement. *Environmental Communication*, *11*(4), 568–586. doi:10.1080/17524032.2017.1308409
Vermunt, J. K., & Magidson, J. (2016). *Technical guide for latent GOLD 5.1: Basic, advanced, and syntax*. Belmont, MA: Statistical Innovations.
Wissenschaft Im Dialog. (2015). *Wissenschaftsbarometer 2015*. Retrieved from http://www.wissenschaft-im-dialog.de/projekte/wissenschaftsbarometer/.
Yankelovich, D., & Meer, D. (2006). Rediscovering market segmentation. *Harvard Business Review*, *84*(2), 122–131.

7.7 Hargittai et al. (2018)

How Do Young Adults Engage With Science and Research on Social Media? Some Preliminary Findings and an Agenda for Future Research.

Hargittai, E., Füchslin, T., & Schäfer, M. S.

This article was originally published in:

Hargittai, E., Füchslin, T., & Schäfer, M. S. (2018). How Do Young Adults Engage With Science and Research on Social Media? Some Preliminary Findings and an Agenda for Future Research. *Social Media + Society, 4*(3), 205630511879772. https://doi.org/10.1177/2056305118797720

Article

Social Media + Society
July-September 2018: 1–10
© The Author(s) 2018
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/2056305118797720
journals.sagepub.com/home/sms

How Do Young Adults Engage With Science and Research on Social Media? Some Preliminary Findings and an Agenda for Future Research

Eszter Hargittai, Tobias Füchslin, and Mike S. Schäfer

Abstract

While considerable research has looked at how people use the Internet for sharing and engaging with various types of content from celebrity news to politics, very little of this work has considered how non-specialists interact with science and research material on social media. This article reviews literature on public engagement with science to note that this area is ripe for research on social-media-based engagement in particular. Drawing on a survey of American young adults' online experiences, we show that using social media for science and research is at least as likely if not more so as engagement with other topics from similarly serious to lighter domains. We also find that platform matters with young adults much more likely to engage with such content on Facebook rather than on Twitter. We end by proposing more focus on this domain in the area of science communication and work on social media.

Keywords

science communication, online participation, sharing, Facebook, Twitter

Introduction

One of the big promises of the Internet is that it allows people of all backgrounds to share content and engage in conversations no longer dependent on traditional media gatekeepers (Benkler, 2006; Jenkins, 2006; Taylor, 2014). A considerable amount of research has examined whether digital media are meeting this potential from creative content sharing to online political participation (for reviews, see Boulianne, 2015; Brake, 2014; Hargittai & Jennrich, 2016), yet very little of this work has focused on social media's potential for sharing or engaging with content related to science and research. It is this gap in the literature that this article addresses. Building on work by others focusing on different types of online participation (e.g., Correa, 2010; Hoffmann, Lutz, & Meckel, 2014; Schradie, 2011), we argue that focusing on engagement with science and research content on social media should be an important part of research on science communication. To illustrate why this area is ripe for investigation, we analyze data about young adults' interactions with such content on Facebook and Twitter in comparison to other types of content showing that it is a popular domain worthy of research.

The lack of focus on how people engage with scientific topics on social media is surprising for two reasons. First, a wide range of issues that were traditionally the purview of scientists such as climate change and vaccination have become popular topics in the 21st century (e.g., Bauer, 2011; Schmidt, Ivanova, & Schäfer, 2013). Scientists and scientific institutions used to enjoy a high level of autonomy and public legitimacy. Over the last few decades, however, science and society have moved closer together (Gibbons, 1999; Weingart, 2001). Not only has science permeated modern societies by providing exponential technological progress, but the public has also started to scrutinize science in light of potential negative consequences of this progress (Scheufele, 2013). Second, "The science of science communication" (Fischhoff & Scheufele, 2013) is interested in how people engage with science and research. Seeing that science needs public legitimacy in order to secure societal support and an influx of resources (Weingart, 2001), researchers have analyzed how science is seen in society and how far the broader

University of Zurich, Switzerland

Corresponding Author:
Eszter Hargittai, Institute of Communication and Media Research (IKMZ), University of Zurich, Andreasstrasse 15, CH-8050 Zurich, Switzerland.
Email: pubs@webuse.org

public supports it and engages with it (for an overview, see Besley, 2013). Early on, such work focused on ways to reduce people's knowledge deficits, assuming that increased knowledge would lead to more support toward the scientific enterprise (e.g., Miller, 1991, 1996). More recently, work has shifted to the idea that the public's engagement with science is more promising for fostering support for science (e.g., Bucchi, 2008).

Given social media's ability to engage people in various conversations, it could be fertile ground for science communication (Brossard, 2013; Brossard & Scheufele, 2013), particularly among younger people who are avid social media users (Mitchell, Gottfried, Barthel, & Shearer, 2016; Pew Research Center, 2018b). Yet, while research on public engagement with science and technology (PEST) has examined the online domain more generally, it has not yet focused strongly on public engagement through social media. To address this gap in the literature, we explore how a group of young adults engages with science and research on such platforms. First, we review the literature on PEST, differentiating forms of engagement, identifying research gaps, and laying out research questions. Then, we describe our methods and data collection followed by a presentation and discussion of our findings about young adults' engagement with science and research on social media to highlight that this is indeed a domain worthy of more scholarly investigation.

Engaging the Public Through Science Communication

Science Communication Models and the Role of Engagement

Traditionally, scholars of science communication have looked at the way science communicates with the public through the lenses of "public understanding of science" (PUS) or the "deficit model" (Bauer, 2016; Bucchi, 2008). These models assume that the public has deficient knowledge about science, a lack of interest, and low trust in it, and that providing the public more information about science can remedy these alleged "deficits" (Bauer, Allum, & Miller, 2007; Durant, 2003). This provision of information is envisioned as a unidirectional transfer, mainly using science journalism and other information channels to transport information to large audiences (Peters, 1996). These audiences, in turn, are seen as passive receptors of information that do not actively engage with the content in any form.

While the deficit model persists in the minds of many communicators (e.g., Pearce et al., 2017), other models consider an active audience that interacts with science-related content (Gerhards & Schäfer, 2008). Recently, there has been a shift toward a model of "public engagement with science and technology" (Bucchi, 2008)—a model that seems tailor-made for the participatory digital technologies of today. It sees the public as an important stakeholder of science and encourages active engagement, ideally as a two-way communication in which both science and the public engage in a dialogue (Bauer et al., 2007).

This emphasis on PEST models in many countries has led to a "participation explosion" (Einsiedel, 2008, p. 173; for an overview, see Rowe & Frewer, 2005). Many forms and activities of public engagement have emerged, "more or less spontaneous, organized and structured, whereby non-experts become involved, and provide their own input to agenda setting, decision-making, policy forming, and knowledge production processes regarding science" (Bucchi & Neresini, 2008, p. 449). But these activities differ greatly in the type of "engagement" with science they aim for and realize (Davies, 2013). They range from more formal, policy-oriented contexts such as consensus conferences, citizen juries, or scenario workshops (e.g., Andersen & Jaeger, 1999; Durant, 1999) to more informal contexts such as visits to science museums and centers (Bell, 2008), science cafés (Dallas, 2006; Navid & Einsiedel, 2012), and citizen science projects (Lewenstein, 2016).

To organize these different kinds of engagement with science conceptually, Rowe and Frewer (2005) have proposed using "public engagement" as an umbrella term under which they distinguish three kinds of activities depending on the directionality of communication between science and the public. They suggest speaking of "*public communication*" if scientists or science communicators merely convey information to the public—as envisaged by the PUS model of science communication; use of the term "*public consultation*" if the public is asked to provide feedback about science-related content to scientists or science communicators; and "*public participation*" only for instances where scientists or science communicators engage in two-way, dialogical communication with members of the public—which comes closest to the ideal of the PEST model of science communication. Similarly, Einsiedel (2008) distinguishes information provision, consultation, as well as involvement and empowerment (where members of the public are involved in steps of the research process) as forms of PEST.

Engagement Online

The Internet has become the most widely used source of science information among Americans (National Science Board, 2018), leading scholars to analyze how science is presented online and how users interact with such content (e.g., Brossard, 2013; Schäfer, 2012). Social media, in particular, provide the potential for such engagement (Brossard, 2013; Brossard & Scheufele, 2013) through their interactive nature (Treem, Dailey, Pierce, & Biffl, 2016). On social media, users can click on science-related content they find interesting, and they can easily comment on this content to express their opinion. Because social media are widespread and have low barriers for engagement, the roles of users versus producers of content are more easily interchangeable. Users can become content providers themselves by sharing content with others, and they can do so instantly, very easily including through mobile devices, from wherever they are (cf. Brossard, 2013; Trench, 2008).

As a result, all three of the above-mentioned forms of public engagement are possible on social media: scientists or science communicators can use social media to convey information, to gather public feedback from users, or be involved in public participation, that is, in two-way communication with members of the public regarding scientific issues. This corresponds well to Rowe and Frewer's (2005) typology of engagement and has been conceptualized in very similar fashion among scholars of online communication (McMillan, 2002).

On social media, users will express their engagement with various forms of "interactivity." One is "*content interactivity*" (also called "media interactivity" or "user-to-medium interactivity," see Boczkowski & Mitchelstein, 2012), which refers to how users "control the information they receive" (Stromer-Galley, 2000, p. 121). It covers content navigation, that is, on which links users click to receive further content (McMillan, 2002). "*Human interactivity*" (or "user-to-user interactivity") describes how individuals interact with other individuals (McMillan, 2002). On social media, this mostly refers to commenting on content (including "likes" and "up votes" that send social cues to other users) and to sharing content with others (cf. Boczkowski & Mitchelstein, 2012). On platforms like Facebook and Twitter, human interactivity increases the likelihood of content being visible to others (Boulianne, 2015; van Dijck, 2013) and therefore the chance for further interactivity. Thus, social media enable various types of engagement with science through different forms of interactivity—all of which can raise the number of participants engaged with science.

Young Adults and Online Engagement With Science

The potential for larger-scale online engagement with science seems particularly important when it comes to young adults. According to the Pew Research Center, 98% of US young adults (defined as 18-29 years) use the Internet (Pew Research Center, 2018a) while 88% use social media (Pew Research Center, 2018b). They are much more likely to get their news online (50%) than from traditional news sources such as newspapers (5%), radio (14%), and television (27%) (Mitchell et al., 2016). Among online sources, social media are particularly important. Young adults are not only the most likely age group on social media (Pew Research Center, 2018b), they are also most likely to see social media as one of their major news sources (32%; Gottfried & Shearer, 2016). When it comes to engaging with news content on social media, 47% of young adults "sometimes" or "often" share and 35% comment on news posts (Mitchell et al., 2016).

Regarding science-related content specifically, young users also rely heavily on the Internet, more than other age groups. According to Science and Engineering Indicators (National Science Board, 2018), 81% of young adults (18-24 years) use the Internet as their primary source of science and technology information. The number is even higher (83%) when this group names their primary source to learn about science and technology (National Science Board, 2018). While these figures establish that the Internet is an important source of science information for young adults, it does not address their active engagement with such content on social media in particular.

Previous Studies on Engagement With Science Online and Their Limitations

While representative data sets exist on how young adults and other groups obtain science content online (National Science Board, 2018; Smith, Marsden, Hout, & Kim, 2016), little research has directly surveyed users to study active engagement on social media. Research on PEST focuses mostly on offline forms of engagement, such as discussions in science cafés or the evaluation of scientific issues by citizens in consensus conferences (e.g., Stilgoe, Lock, & Wilsdon, 2014).

Scholarship about social media content related to science has analyzed debates (Dalrymple, Young, & Tully, 2016; Lörcher & Neverla, 2015), has reconstructed communicative networks and core topics around scientific issues (e.g., Büchi, 2017; Pearce, Holmberg, Hellsten, & Nerlich, 2014; Veltri, 2013), has focused on the activity of actors such as non-governmental organizations and journalists (e.g., Dalrymple et al., 2016; Hopke & Simis, 2015; Pearce et al., 2014), and has inferred academics' motives to use such platforms (e.g., Mewburn & Thomson, 2013), but has not examined active engagement. General survey studies that exist in this domain tend to examine the extent to which respondents use social media, among other sources, to gather information about science focusing on consumption activities rather than active participation (Anderson, Brossard, & Scheufele, 2010; National Science Board, 2018; Smith et al., 2016; Su, Akin, Brossard, Scheufele, & Xenos, 2015).

Regarding platforms, work on social media communication about science has mostly looked at blogs (e.g., A. E. Bauer, 2013; Kouper, 2010), microblogs (e.g., Knight & Kaye, 2016), discussion forums (e.g., Hine, 2014; Lörcher & Neverla, 2015), or comment features in general (e.g., Jaspal, Nerlich, & Koteyko, 2013; Kouper, 2010; Len-Rios, Bhandari, & Medvedeva, 2014). Few science-focused studies have analyzed social network sites like Facebook (as an exception, see Kahle, Sharon, & Baram-Tsabari, 2016). The lack of attention to these platforms is surprising, because they host a considerable amount of scientific content (Brossard, 2013) and are among the most popular social media both in the United States (comScore, 2016) and elsewhere (Alexa, 2017).

In addition, studies that consider social media tend to restrict their analyses to one specific platform such as Twitter (e.g., Knight & Kaye, 2016) or one type of platform such as science blogs (e.g., Fecher & Kaiser, 2015). Given that users have been shown to turn to several platforms for different purposes, and to integrate them into their personal media repertoires in varying ways (Hasebrink & Popp, 2006), analysis of user behavior across platforms is warranted.

Our article fills these gaps by analyzing data on a diverse group of young adults—the most likely population to use social media—about their engagement with science-related content on two social media platforms, Twitter and Facebook, in addition to sharing such content with others on email. To do so, we consider user engagement with scientific issues in the context of other topical domains. Such comparisons are relevant, because science and research often entail specialist knowledge presented with complex methodological tools and a certain nomenclature, and have therefore been interpreted as "unobtrusive" issues (Dunwoody, 2014; Fischhoff & Scheufele, 2013). Therefore, engagement with science and research on social media might differ in degree and character from engagement with other issues that are partly equally "unobtrusive" but partly also differ from science and research in that respect.

We ask the following research questions:

RQ1. To what extent do young adults use the Internet for science and research content as compared to other content?

RQ2. How does online engagement through clicking and commenting on content about science and research compare to engaging similarly with other types of content?

RQ3. How does sharing science and research content on social media compare to similar engagement with other topics?

RQ3a. How does sharing science and research content differ by platform, is it more popular on Facebook or Twitter, and how do these compare to email?

RQ3b. How does sharing other types of content differ by platform, are they more popular on Facebook or Twitter, and how do they compare to email?

Methods

The data set comes from a larger project whose main purpose was to study young adults' Internet uses where young adults are defined as people in their late teens and early 20s. Because science communication was not the overall project's focus, the available questions are not as nuanced as would be ideal for exploring young adults' engagement with science on social media in depth. There were nonetheless some related questions that have heretofore been unexplored in the literature and give an opportunity to explore engagement with science and research on social media compared to other topics.

Data Collection

The sample is the third wave of a panel study that started in 2009 with 1,115 participants, followed with a second wave of data collection in 2012, and a third wave in 2016, which is the data set used here. In 2009, we worked with the non-flagship campus of a Midwestern state's university system to administer the survey to its first-year population. None of the authors or people associated with the data collection were affiliated with this university, it was chosen thanks to the socioeconomic and racial diversity of its student body as well as the fact that it had a class required of all first-year students to take, making it possible to reach a random sample of its student body. Findings from the analyses of the 2009 wave were replicated on national samples when it comes to the social media uses of the sample suggesting that experiences of this young adult group are not solely representative of them (Nielsen, 2009).

The 2016 sample is representative of both the 2009 and 2012 samples on gender, race/ethnicity, and parental education except that it has fewer African Americans (about the same proportion, however, as in 2012, 8% compared to 11% in 2009). Also in terms of Internet experiences and skills, the 2016 group is representative of the earlier samples on such basic measures as autonomy of use, frequency of use, and Internet skills.

The data set includes responses from 385 young adults surveyed in summer 2016 through postal mail in the United States. We sent the 2016 survey to the 547 participants who responded in 2012 for a 70% response rate (73% of those for whom the surveys did not bounce; 35% of 2009 participants). The original 2009 survey included questions about demographic and socioeconomic characteristics.

Measuring Sociodemography

We asked respondents in what year they were born to calculate their age. Gender was a binary question of male or female. We used parental education as a proxy for socioeconomic status (SES) since more traditional measures of SES do not work well with a group of young adults. We asked respondents to report the education level of both their mother and their father from the following categories: (a) less than high school degree, (b) high school degree, (c) some college, (d) college degree (e.g., BA, BS, BSE), (e) advanced graduate (e.g., master's, professional, PhD, MD, EdD). We aggregated this information by considering the highest level of education that either parent. That is, if a respondent has a father with a high school education and a mother with a college degree, then we recoded the parental education variable for this respondent as "college degree." Following US Census conventions (US Census Bureau, 2000), we asked respondents to indicate if they were of Hispanic or Latino origin. Then, we asked people's race based on the following categories: (a) White/Anglo/Caucasian/Middle Eastern, (b) Black/African American, (c) Asian, (d) American Indian or Alaskan Native, (e) Other. Most responses in the "Other" category indicated Hispanic origin and were coded accordingly.

Measuring Forms of Engagement With Content

The survey asked several questions about how respondents engage with various types of content online. First, it inquired generally about use of the Web for various topics: "How often, if ever, do you use the Internet or the Web for the following?" Then, the survey asked, "Do you ever engage with—such as *click or comment on*—the following types of content others share on social media (like on Facebook or Twitter)?" While it is not ideal that this question collapsed clicking and commenting in its example of what is meant by "engaging with," it does measure engagement. The survey also included the following question: "Have you shared any of the following content in the past year? For each, please indicate if you have shared it (a) on Facebook, (b) on Twitter, (c) through email, (d) through another site/service, or whether you did not share such content at all. For each, check all that apply." In all of the above cases, "science/research" was one of the topical domains listed—a domain that respondents in countries like Switzerland associate mostly with medical research and the natural sciences, followed by engineering, the social sciences, and humanities (Schäfer, Füchslin, Metag, Kristiansen, & Rauchfleisch, 2018). We disaggregated the question by platform as Facebook and Twitter function differently. For example, connections on the former mostly concern mutual connections and are in a somewhat private setting, while the latter tends to be more public and does not necessarily concern mutual connections with friends and acquaintances (thus allowing for a potentially wider reach).

In addition to measuring engagement with science content online, we also inquired about other types of content to offer points of comparison. In this article, we compare engagement with "science, research" to "current events" and "political campaigns and election news" to cover political news, a generally popular topic; engagement with "health, fitness" as a topic related to science and research; "finance, investing" as a different topic, but one of a similarly serious nature; and "entertainment and celebrity news," a lighter topic that research has shown is of particular interest to young adults using social media (Hargittai & Litt, 2011). In the survey, we purposefully listed "health, fitness" before "science, research" to signal to respondents that we considered "health, fitness" a different domain. Topical comparisons allow us to establish the relative popularity of science engagement.

The Sample

In total, 60% of the 385 respondents are female. Most respondents are either 25 or 26 years of age ($M = 25.3$) so we do not include this variable in the analyses. Less than half (43.4%) are White, 23.6% are Asian/Asian American, 22.7% are Hispanic, 7.5% are African American, and less than 1% are Native American. About a quarter (24.8%) come from families where neither parent has more than a high school degree, and an additional 25.6% have parents who did not complete more than some college education. The majority (91%) completed college, half of them in 4 years, the other half in more time. The fact that the majority of respondents have a college degree likely skews the sample toward higher levels of engagement with science and research than would be the case otherwise, something that is important to keep in mind when considering the larger-level implications of the findings. It is important to note, however, that only 15% of the sample is a student so the vast majority are not enrolled in school at the time of this data collection.

In terms of their Internet uses, they range from using it just a couple of hours a week to 8 hr a day, have access at anywhere from 1 to 10 locations, and over half (57%) use smartphones with unlimited data plans. Participants' Web-use skills vary from barely understanding Internet-related terms to considerable familiarity with digital media (27-item index; Cronbach's $\alpha = .95$). On the whole, while everyone in the sample has been an Internet user for many years, their online experiences vary considerably.

Engaging With Science and Research on Social Media

The first research question asked in general terms to what extent young adults use the Internet for science and research as compared to other content. Results show that most young adults turn to the Internet for information about science and research (see Table 1 for all of the results discussed below). Almost all respondents (95.6%) do this, and almost two-thirds (62.9%) do so weekly. The only topic more popular with this group is using the Internet for current events, which almost everybody has done at some point (99.5%) and most do regularly (91.4%). Comparing these figures to the prevalence of using the Internet for other topics, we find that health (96.4% ever, 61.6% weekly or more) and celebrity news (95.0% ever, 63.7% weekly or more) are very similar in popularity (no statistically significant differences), whereas finance and investing is considerably less popular (77.0% ever, 30.1% weekly) as is ever using the Internet for political campaigns or elections news (91.2%).

The second research question asked how clicking and commenting on science and research topics on social media compares to such engagement with others types of content. The majority (81.3%) of the surveyed young adults have clicked on or commented upon information related to science and research before, and more than a third of them (37%) do so weekly. For having done this ever, there is no statistically significant difference when compared to current events although young adults are more likely to engage with such content weekly or more often (54.6%). Such engagement with health and fitness materials is similarly popular, 83.6% have ever done so, and 42.3% do so weekly (no statistical significance in difference). In line with results about use of the Internet for finance and investing, it is also less

Table 1. Use of the Internet and social media in particular to engage with content about science and research, and other topics ($N = 385$).

	Science, research	Current events	Political campaigns, election news[a]	Health	Finance, investing[b]	Entertainment, celebrity news
Uses the Internet for						
Ever	95.6	99.5***	91.2*	96.4	77.0***	95.0
Weekly or more	62.9	91.4***	61.0	61.6	30.6***	63.7
Engages with (clicks/comments on)						
Ever	81.3	83.6	70.1***	83.6	66.2***	76.6
Weekly or more	37.0	54.6***	34.0	42.3	13.8***	33.6
Has shared links to						
On either Facebook or Twitter	39.7	59.4***	26.2***	37.5	14.1***	41.8
On Facebook[c]	44.4	65.0***	28.2***	41.2	15.0***	45.3
On Twitter[c]	9.9	23.1***	14.4	9.3	5.6	21.6***
On email	20.3	16.5	6.0***	14.6	10.7***	8.6***
In any way (includes other sites and email)	53.5	68.9***	31.2***	49.5	24.4***	46.8

Difference in means tests across topic areas.
[a]For general Internet use, this topic stated the more general "politics."
[b]For sharing, this topic stated "finance, economy, investing."
[c]Figures in this row are restricted to users of the platform.
*$p < .01$; ***$p < .001$.

popular on social media with two-thirds (66.2%) having ever clicked or commented on such content and 13.8% doing so weekly. The same holds for political campaigns and election news when it comes to ever engaging with such content (70.1%), although we find no difference among the proportion who do so regularly (34.0%). Over three-fourths (76.6%) of the sample have engaged with entertainment and celebrity news in such a way and a third (33.6%) have done so weekly, figures that are not statistically significantly different from engagement with science and research. Overall, these figures suggest that clicking and commenting on science and research content on social media is a widespread phenomenon among young adults, and more popular than engaging with certain other serious topics (i.e., health, finance/economy/investing, political campaigns/election news).

Finally, we asked how the prevalence of sharing science and research content on social media compared to other content (RQ3), how this differed by platform (RQ3a), and whether we observe platform differences compared to other content (RQ3b). The majority of respondents (84.5%) use Facebook. Considerably fewer (42.1%) use Twitter, and fewer use both (37.9%). Looking at sharing on either Facebook or Twitter, two-fifths (39.7%) of respondents reported having done so in the past year. This is similar to the 37.5% who had shared content about health and fitness, and considerably higher than the 14.4% who had shared content about finance and investing as well as political campaigns and election news (26.2%). Sharing current events information is again the most popular at 59.4%, while sharing celebrity or entertainment news is similar to science and research content at 41.8%. Note that these percentages concern the full sample, not just users of these platforms, as there is value in identifying sharing of content for the whole group. The following set of analyses about sharing on specific platforms controls for use of each respective platform.

Next, we looked at how sharing of science and research content compares across Facebook, Twitter, and email (RQ3a). While 44.4% of respondents who use Facebook had posted such content on the site, only 9.9% among Twitter users had used that platform for sharing such material. Email is much more common than Twitter for such content sharing at 20.3%.

We then looked at whether platform-specific sharing differs for other types of content (RQ3b). Regarding sharing on Facebook, more people share current events (65.0%) than research and science content (44.4%). There is no statistical significance between proportion sharing health (37.5%) as well as entertainment and celebrity news (41.8%). A significantly lower portion, however, share political campaigns/election news (28.2%) as well as finance, economy, investing content (15.0%).

Sharing on Twitter looks different, however. Consistent with all other types of engagement, current events sharing is the most common (23.1%), but we also observe that sharing entertainment and celebrity news is more popular on this platform at 21.6% than science and research at 9.9%. We observe no statistically significant differences compared to political campaigns/election news (14.4%), health (9.3%), and finance, economy, investing (5.6%).

Email sharing, a largely ignored social medium in the study of content sharing these days, is the one type of sharing where nothing is more popular than the sharing of science and research (20.3%) compared to current events at 16.5%, and health at 14.6%, neither of which is a statistically significant difference. Young adults use this medium considerably less for sharing political campaigns and election news (6.0%); finance, economy, investing (10.7%); as well as entertainment and celebrity news (8.6%).

In sum, the above findings suggest that engaging on social media (as well as on email) with science and research content is relatively popular compared to several other topics. Indeed, the only topic that consistently trumps it in popularity is "current events," a category that can encompass considerable variation in content (including some content that may be related to science and research) and is thus not as helpful as more focused categories such as health and finance, neither of which is more popular than science and research—indeed, the latter is less popular.

Discussion and Conclusion

Our results underline the importance of the Internet, and particularly social media, for young adults' engagement with science and research. The group of young adults we studied widely uses the features provided by social media to engage with such content. They do this more than they engage with finance and investing content as well as political campaigns and election news during a US presidential election year. Sharing science and research content on social media also rivals sharing content about health and fitness as well as entertainment and celebrity news. These findings underline that further analyses of engagement with science and scientific issues on social media are warranted.

Furthermore, our findings highlight the importance of disaggregating online engagement by platform. While Twitter has been shown to be a valuable platform for expert debates about science and research (e.g., Pearce et al., 2014; Yeo et al., 2016), it is not widely used among young adults for science content. Only 4.2% of the sample have used the microblogging platform to share links about science and research, in other words, less than 10% of those who use that platform. This is considerably lower than the 44.4% of Facebook users who have shared such content on that platform. Despite easier researcher access to user content on micro/blogs and forums, future research focusing on people's Facebook use would be more relevant to analyze interactions between science and society. From the perspective of science communication, efforts to reach and engage larger audiences through people's sharing should be more focused on Facebook than Twitter as the latter does not seem to be the place where such action occurs among young adults.

While the article offers a unique look at engaging with science content online, the study has considerable limitations that future research should address. From a conceptual perspective, it is important to note that this study did not gather detailed data about either level of engagement or type of science content consulted. Further studies will hopefully be able to disaggregate between types of interactivity identified in the literature (Boczkowski & Mitchelstein, 2012; Stromer-Galley, 2000) to examine how human interactivity and medium interactivity compare. In addition, future research should gather more specific data about the type of science content users engage on social media. Also, limiting the sample to young adults prevents generalizability to the wider population, but this is the segment of the population most likely to use social media, and we know of no data set with the detailed social media engagement measures about science content presented here that would allow for more generalizable analyses.

In sum, the article makes three contributions to research on social media use as well as science communication. First, social media are an important site for engagement with science and research among young adults rivaling such content as health and fitness but also entertainment and celebrity news, and thus merit focus in the literature on science communication as well as on more general studies of social media use. Second, these users are much more likely to have clicked or commented on such content than to have shared it. The active engagement of contributing to conversations by being the one to set the agenda, that is, putting up a post, is much less common than reacting to existing posts. Future research could explore why this is and how non-specialists may be encouraged to do more of the latter. Third, platforms matter. Facebook is a much more likely site for content sharing about science and research than Twitter. The discrepancy by platform is the largest for science and research content compared to health and fitness, finance and investing, as well as entertainment and celebrity news. These results help establish important baselines about how young adults engage with science and research online while encouraging future research to delve deeper into why the patterns we identify may exist, and examining in more detail the types of engagement around these topics.

Acknowledgements

The authors are grateful to the John D. and Catherine T. MacArthur Foundation and the Robert and Kaye Hiatt Fund at Northwestern University for their support of the project upon which this study is based. They thank the numerous research assistants over the years who assisted the data collection effort, especially Cierra Levy, Sam Mandlsohn, Richard Herndon, Devon Moore, and Bob Babich for their work on the last wave of the project.

Declaration of Conflicting Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

Alexa. (2017). *Top sites in United States*. Retrieved from http://www.alexa.com/topsites/countries/US

Andersen, I.-E., & Jaeger, B. (1999). Scenario workshops and consensus conferences: Towards more democratic decision-making. *Science and Public Policy*, *26*, 331–340.

Anderson, A. A., Brossard, D., & Scheufele, D. A. (2010). The changing information environment for nanotechnology: Online audiences and content. *Journal of Nanoparticle Research*, *12*, 1083–1094. doi:10.1007/s11051-010-9860-2

Bauer, A. E. (2013). Astropixie: Astronomy engagement through blogging and Twitter. In J. Barnes, C. Shupla, J. G. Manning, & M. G. Gibbs (Eds.), *Astronomical Society of the Pacific Conference Series*, *Communicating Science: A National Conference on Science Education and Public Outreach: Proceedings of a Conference held at Tucson, Arizona, USA 4-8 August 2012* (Vol. 473, p. 173). San Francisco: Astronomical Society of the Pacific.

Bauer, M. W. (2011). Public attention to science 1820–2010: A "longue durée" picture. In S. Rödder, M. Franzen, & P. Weingart (Eds.), *Sociology of the Sciences Yearbook: The sciences' media connection—Communication to the public and its repercussions* (pp. 35–58). Dordrecht, The Netherlands: Springer.

Bauer, M. W. (2016). Results of the essay competition on the "deficit concept." *Public Understanding of Science*, *25*, 398–399. doi:10.1177/0963662516640650

Bauer, M. W., Allum, N., & Miller, S. (2007). What can we learn from 25 years of PUS survey research? Liberating and expanding the agenda. *Public Understanding of Science*, *16*, 79–95. doi:10.1177/0963662506071287

Bell, L. (2008). Engaging the public in technology policy: A new role for science museums. *Science Communication*, *29*, 386–398. doi:10.1177/1075547007311971

Benkler, Y. (2006). *The wealth of networks: How social production transforms markets and freedom*. New Haven, CT: Yale University Press.

Besley, J. C. (2013). The state of public opinion research on attitudes and understanding of science and technology. *Bulletin of Science, Technology & Society*, *33*, 12–20. doi:10.1177/0270467613496723

Boczkowski, P. J., & Mitchelstein, E. (2012). How users take advantage of different forms of interactivity on online news sites: Clicking, e-mailing, and commenting. *Human Communication Research, 38(1)*, 1–22. doi:10.1111/j.1468-2958.2011.01418.x

Boulianne, S. (2015). Social media use and participation: A meta-analysis of current research. *Information, Communication & Society*, *18*, 524–538. doi:10.1080/1369118X.2015.1008542

Brake, D. R. (2014). Are we all online content creators now? Web 2.0 and digital divides. *Journal of Computer-Mediated Communication*, *19*, 591–609. doi:10.1111/jcc4.12042

Brossard, D. (2013). New media landscapes and the science information consumer. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(Suppl. 3), 14096–14101. doi:10.1073/pnas.1212744110

Brossard, D., & Scheufele, D. A. (2013). Science, new media, and the public. *Science*, *339*(6115), 40–41. doi:10.1126/science.1232329

Bucchi, M. (2008). Of deficits, deviations and dialogues: Theories of public communication of science. In M. Bucchi & B. Trench (Eds.), *Handbook of public communication of science and technology* (pp. 57–76). London, England: Routledge.

Bucchi, M., & Neresini, F. (2008). Science and public participation. In E. J. Hackett, O. Amsterdamska, M. Lynch, & J. Wajcman (Eds.), *The handbook of science and technology studies* (pp. 449–472). Cambridge, MA: The MIT Press.

Büchi, M. (2017). Microblogging as an extension of science reporting. *Public Understanding of Science*, *26*, 953–968. doi:10.1177/0963662516657794

comScore. (2016). *comScore ranks the top 50 U.S. digital media properties for February 2016*. Retrieved from https://www.comscore.com/Insights/Rankings/comScore-Ranks-the-Top-50-US-Digital-Media-Properties-for-February-2016

Correa, T. (2010). The participation divide among "online experts": Experience, skills and psychological factors as predictors of college students' web content creation. *Journal of Computer-Mediated Communication*, *16*, 71–92. doi:10.1111/j.1083-6101.2010.01532.x

Dallas, D. (2006). Café scientifique—Déjà vu. *Cell*, *126*, 227–229.

Dalrymple, K. E., Young, R., & Tully, M. (2016). "Facts, not fear": Negotiating uncertainty on social media during the 2014 Ebola crisis. *Science Communication*, *38*, 442–467. doi:10.1177/1075547016655546

Davies, S. R. (2013). Constituting public engagement: Meanings and genealogies of PEST in two UK studies. *Science Communication*, *35*, 687–707.

Dunwoody, S. (2014). Science journalism. In M. Bucchi & B. Trench (Eds.), *Routledge handbook of public communication of science and technology* (pp. 27–39). Abingdon, UK: Routledge.

Durant, J. (1999). Participatory technology assessment and the democratic model of the public understanding of science. *Science and Public Policy*, *26*, 313–319.

Durant, J. (2003). *From Deficit to Dialogue.* Presentation, am Deutschen Museum, Munich, Germany.

Einsiedel, E. F. (2008). Public participation and dialogue. In M. Bucchi & B. Trench (Eds.), *Handbook of public communication of science and technology* (pp. 173–184). London, England: Routledge.

Fecher, B., & Kaiser, J. (2015). Collapsing ivory towers? A hyperlink analysis of the German academic blogosphere [Impact of Social Sciences Blog]. Retrieved from http://blogs.lse.ac.uk/impactofsocialsciences/2015/09/29/collapsing-ivory-towers-a-hyperlink-analysis/

Fischhoff, B., & Scheufele, D. A. (2013). The science of science communication. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(Suppl. 3), 14031–14032. doi:10.1073/pnas.1312080110

Gerhards, J., & Schäfer, M. S. (2009). Two normative models of science in the public sphere: Human genome sequencing in German and US mass media. *Public Understanding of Science*, *18*, 437–451.

Gibbons, M. (1999). Science's new social contract with society. *Nature*, *402*, C81–C84.

Gottfried, J., & Shearer, E. (2016). *News use across social media platforms 2016*. Washington, DC: Pew Research Center.

Hargittai, E., & Jennrich, K. (2016). The online participation divide. In M. Lloyd & L. A. Friedland (Eds.), *The communication crisis in America, and how to fix it* (pp. 199–213). New York, NY: Palgrave Macmillan.

Hargittai, E., & Litt, E. (2011). The Tweet smell of celebrity success: Explaining variation in Twitter adoption among a diverse group of young adults. *New Media & Society*, *13*, 824–842. doi:10.1177/1461444811405805

Hasebrink, U., & Popp, J. (2006). Media repertoires as a result of selective media use: A conceptual approach to the analysis of patterns of exposure. *Communications*, *31*, 369–387.

Hine, C. (2014). Headlice eradication as everyday engagement with science: An analysis of online parenting discussions. *Public Understanding of Science*, *23*, 574–591. doi:10.1177/0963662512453419

Hoffmann, C. P., Lutz, C., & Meckel, M. (2014). Content creation on the Internet: A social cognitive perspective on the participation divide. *Information, Communication & Society*, *18*, 696–716. doi:10.1080/1369118X.2014.991343

Hopke, J. E., & Simis, M. (2015). Discourse over a contested technology on Twitter: A case study of hydraulic fracturing. *Public Understanding of Science*, *26*, 105–120. doi:10.1177/0963662515607725

Jaspal, R., Nerlich, B., & Koteyko, N. (2013). Contesting science by appealing to its norms: Readers discuss climate science in the Daily Mail. *Science Communication*, *35*, 383–410. doi:10.1177/1075547012459274

Jenkins, H. (2006). *Convergence culture: Where old and new media collide*. New York: New York University Press.

Kahle, K., Sharon, A. J., & Baram-Tsabari, A. (2016). Footprints of fascination: Digital traces of public engagement with particle physics on CERN's social media platforms. *PLoS ONE*, *11*, e0156409. doi:10.1371/journal.pone.0156409

Knight, C. G., & Kaye, L. K. (2016). "To tweet or not to tweet?" A comparison of academics' and students' usage of Twitter in academic contexts. *Innovations in Education and Teaching International*, *53*, 145–155. doi:10.1080/14703297.2014.928229

Kouper, I. (2010). Science blogs and public engagement with science: Practices, challenges, and opportunities. *Journal of Science Communication*, *09*(01). Retrieved from https://doi.org/10.22323/2.09010202

Len-Rios, M. E., Bhandari, M., & Medvedeva, Y. S. (2014). Deliberation of the scientific evidence for breastfeeding: Online comments as social representations. *Science Communication*, *36*, 778–801. doi:10.1177/1075547014556195

Lewenstein, B. V. (2016). Can we understand citizen science? *Journal of Science Communication*, *15*(1). Retrieved from http://jcom.sissa.it/sites/default/files/documents/JCOM_1501_2016_E.pdf

Lörcher, I., & Neverla, I. (2015). The dynamics of issue attention in online communication on climate change. *Media and Communication*, *3*(1), 17–33. doi:10.17645/mac.v3i1.253

McMillan, S. J. (2002). Exploring models of interactivity from multiple research traditions: Users, documents, and systems. In L. A. Lievrouw & S. Livingstone (Eds.), *Handbook of new media: Social shaping and consequences of ICTs* (Vol. 2, pp. 205–229). London, England: SAGE.

Mewburn, I., & Thomson, P. (2013). Why do academics blog? An analysis of audiences, purposes and challenges. *Studies in Higher Education*, *38*, 1105–1119. doi:10.1080/03075079.2013.835624

Miller, J. D. (1991). *The public understanding of science and technology in the U.S.: Report to the U.S. National Science Foundation*. DeKalb, IL: National Opinion Research Centre, University of Chicago.

Miller, J. D. (1996). Scientific literacy for effective citizenship. In R. E. Yager (Ed.), *Science/technology/society as reform in science education* (pp. 185–204). Albany: State University of New York Press.

Mitchell, A., Gottfried, J., Barthel, M., & Shearer, E. (2016). *The modern news consumer: News attitudes and practices in the digital era*. Retrieved from http://assets.pewresearch.org/wp-content/uploads/sites/13/2016/07/07104931/PJ_2016.07.07_Modern-News-Consumer_FINAL.pdf

National Science Board. (2018). *Science and technology: Public attitudes and understanding* (Science and Engineering Indicators). Arlington, VA: Author.

Navid, E. L., & Einsiedel, E. F. (2012). Synthetic biology in the Science Café: What have we learned about public engagement? *Journal of Science Communication*, *11*(4). Retrieved from https://doi.org/10.22323/2.11040202

Nielsen (2009). The more affluent and more urban are more likely to use social networks. Retrieved from http://www.nielsen.com/us/en/newswire/2009/the-more-affluent-and-more-urban-are-more-likely-to-use-social-networks.html

Pearce, W., Grundmann, R., Hulme, M., Raman, S., Hadley Kershaw, E., & Tsouvalis, J. (2017). Beyond counting climate consensus. *Environmental Communication*, *11*, 723–730. doi:10.1080/17524032.2017.1333965

Pearce, W., Holmberg, K., Hellsten, I., & Nerlich, B. (2014). Climate change on Twitter: Topics, communities and conversations about the 2013 IPCC Working Group 1 report. *PLoS ONE*, *9*(4), e94785. doi:10.1371/journal.pone.0094785

Peters, H. P. (1996). Massenmedien als Vermittler zwischen Experten und Nichtexperten [Mass media as brokers between experts and non-experts]. In M. Kerner (Ed.), *Aufstand Der Laien: Expertentum Und Demokratie in Der Technisierten Welt* [rise of the laymen: expertise and democracy in an engineered world] (pp. 61–88). Aachen, Germany: Thouet.

Pew Research Center. (2018a). *Internet/broadband fact sheet*. Retrieved from http://www.pewinternet.org/fact-sheet/internet-broadband/

Pew Research Center. (2018b). *Social media fact sheet*. Retrieved from http://www.pewinternet.org/fact-sheet/social-media/

Rowe, G., & Frewer, L. J. (2005). A typology of public engagement mechanisms. *Science, Technology, & Human Values*, *30*, 251–290.

Schäfer, M. S. (2012). Online communication on climate change and climate politics: A literature review. *Wiley Interdisciplinary Reviews: Climate Change*, *3*, 527–543. doi:10.1002/wcc.191

Schäfer, M. S., Füchslin, T., Metag, J., Kristiansen, S., & Rauchfleisch, A. (2018). The different audiences of science communication: A segmentation analysis of the Swiss population's perceptions of science and their information and media use patterns. *Public Understanding of Science*. doi:10.1177/0963662517752886

Scheufele, D. A. (2013). Communicating science in social settings. *Proceedings of the National Academy of Sciences of the United States of America*, *110*, 14040–14047. doi:10.1073/pnas.1213275110

Schmidt, A., Ivanova, A., & Schäfer, M. S. (2013). Media attention for climate change around the world: A comparative analysis of newspaper coverage in 27 countries. *Global Environmental Change*, *23*, 1233–1248.

Schradie, J. (2011). The digital production gap: The digital divide and Web 2.0 collide. *Poetics*, *39*, 145–168. doi:10.1016/j.poetic.2011.02.003

Smith, T. W., Marsden, P., Hout, M., & Kim, J. (2016). *General Social Surveys, 1972-2016* [Machine-readable data file] (Sponsored by National Science Foundation). Available from gssdataexplorer.norc.org

Stilgoe, J., Lock, S. J., & Wilsdon, J. (2014). Why should we promote public engagement with science? *Public Understanding of Science*, *23*(1), 4–15. doi:10.1177/0963662513518154

Stromer-Galley, J. (2000). On-line interaction and why candidates avoid it. *Journal of Communication*, *50*(4), 111–132. doi:10.1093/joc/50.4.111

Su, Y.-F., Akin, H., Brossard, D., Scheufele, D. A., & Xenos, M. A. (2015). Science news consumption patterns and their implications for public understanding of science. *Journalism & Mass Communication Quarterly*, *92*, 597–616. doi:10.1177/1077699015586415

Taylor, A. (2014). *The people's platform: Taking back power and culture in the digital age*. New York, NY: Metropolitan Books.

Treem, J. W., Dailey, S. L., Pierce, C. S., & Biffl, D. (2016). What we are talking about when we talk about social media: A framework for study. *Sociology Compass*, *10*, 768–784. doi:10.1111/soc4.12404

Trench, B. (2008). Internet: Turning science communication inside-out? In M. Bucchi & B. Trench (Eds.), *Handbook of public communication of science and technology* (pp. 185–198). London, England: Routledge.

US Census Bureau. (2000). *United States Census 2000*. Retrieved from https://www.census.gov/main/www/cen2000.html

van Dijck, J. (2013). *The culture of connectivity: A critical history of social media*. New York, NY: Oxford University Press.

Veltri, G. A. (2013). Microblogging and nanotweets: Nanotechnology on Twitter. *Public Understanding of Science*, *22*, 832–849. doi:10.1177/0963662512463510

Weingart, P. (2001). *Die Stunde der Wahrheit? Zum Verhältnis der Wissenschaft zu Politik, Wirtschaft und Medien in der Wissensgesellschaft* [The moment of truth? On science's relationship with politics, economics and the media in the knowledge society]. Weilerswist, Germany: Velbrück.

Yeo, S. K., Liang, X., Brossard, D., Rose, K. M., Korzekwa, K., Scheufele, D. A., & Xenos, M. A. (2017). The case of #arseniclife: Blogs and Twitter in informal peer review. *Public Understanding of Science*, *26*, 937–952. doi:10.1177/0963662516649806

Author Biographies

Eszter Hargittai (PhD, Princeton University) is Professor and Chair of Internet Use and Society at the University of Zurich's Institute for Communication and Media Research (IKMZ). Her research focuses on differences in people's Internet uses. She is currently editing the *Handbook of Digital Inequality*.

Tobias Füchslin (MA, University of Zurich) is a research and teaching associate at the University of Zurich's Department of Communication and Media Research (IKMZ). His research interests include science communication, scientific and digital literacies, and information seeking.

Mike S. Schäfer (PhD, Free University of Berlin/MA, University of Leipzig) is a professor of communication at the University of Zurich. His research interests include climate change communication, science communication, and public sphere theory.

7.8 Kovic and Füchslin (2018)

Probability and conspiratorial thinking.

Kovic, M., & Füchslin, T.

This article was originally published in:

Kovic, M., & Füchslin, T. (2018). Probability and conspiratorial thinking. *Applied Cognitive Psychology, 32*(3), 390–400. https://doi.org/10.1002/acp.3408

Received: 16 August 2017 | Revised: 5 February 2018 | Accepted: 18 February 2018
DOI: 10.1002/acp.3408

WILEY

SHORT PAPER - 5000 WORDS OR LESS

Probability and conspiratorial thinking

Marko Kovic[1,2,3] | Tobias Füchslin[1,4]

[1]Swiss Skeptics–Association for Critical Thinking, Zurich, Switzerland
[2]Zurich Institute of Public Affairs Research, Zurich, Switzerland
[3]GmbH, Zurich, Switzerland
[4]Department of Communication and Media Research, University of Zurich, Zurich, Switzerland

Correspondence
Marko Kovic, Swiss Skeptics–Association for Critical Thinking, Zurich, Switzerland.
Email: markokovic@gmail.com

Summary

Conspiracy theories as alternative explanations for events and states of affairs enjoy widespread popularity. We test one possible explanation for why people are prone to conspiratorial thinking: We hypothesize that conspiratorial thinking as an explanation for events increases as the probability of those events decreases. In order to test this hypothesis, we have conducted five experiments in which participants were exposed to different information about probabilities of fictional events. The results of all experiments support the hypothesis: The lower the probability of an event, the stronger participants embrace conspiratorial explanations. Conspiratorial thinking, we conclude, potentially represents a cognitive heuristic: A coping mechanism for uncertainty.

KEYWORDS
cognitive biases, cognitive heuristics, conspiracy theories, conspiratorial reasoning, probability

1 | INTRODUCTION: CONSPIRATORIAL BELIEFS AND ERRORS IN PROBABILISTIC THINKING

A conspiracy theory is a particular kind of alternative explanation for some event or some state of affairs in the world. Conspiracy theories posit that the "common explanation" for an event or state of affairs is false, and that, in reality, individuals or organizations have caused the event or state of affairs for nefarious reasons (Clarke, 2002; Keeley, 1999). From a purely epistemological point of view, conspiracy theories represent beliefs that are not justified very well, or not at all. This means that the epistemic shortcoming of conspiratorial beliefs is not contingent on their truth status: Even though the propositional content of conspiracy theories can be accidentally true, the way the belief in conspiracy theories is justified is defective. In that sense, conspiracy theories' "crippled" (Sunstein & Vermeule, 2009) epistemology represents a case of the Gettier problem (Gettier, 1963), or, more generally, a case of epistemic luck (Pritchard, 2004).

Given the epistemic shortcoming of conspiracy theories, the prevalence of conspiratorial thinking is somewhat surprising: Rather than being a fringe occurrence, belief in conspiracy theories is fairly common (Oliver & Wood, 2014a, 2014b), and, furthermore, belief in conspiracy theories can affect real-world behavior and decision-making (Jolley & Douglas, 2014b, 2014a; K. Douglas, Sutton, Jolley, & Wood, 2015). The fact that conspiracy theories are an everyday phenomenon means that accounts of conspiratorial thinking as pathologies (Barron, Morgan, Towell, Altemeyer, & Swami, 2014; Bentall, Kinderman, & Kaney, 1994; Darwin, Neave, & Holmes, 2011) or consequences of maladaptive traits (Swami, Weis, Lay, Barron, & Furnham, 2016) probably offer only a partial explanation. Although it is possible that a subset of conspiratorial reasoning is caused by pathologies of the mind and anomalous personality traits, it is highly improbable that every conspiratorial belief can be explained in this manner. A different and complementary perspective on conspiratorial reasoning is not one of anomaly, but of normalcy: Conspiratorial reasoning as a consequence of general and universal cognitive limitations (Boudry & Braeckman, 2012). From this point of view, cognitive patterns in the context of conspiracy theories, such as the need for cognitive closure and explanatory completeness (Marchlewska, Cichocka, & Kossowska, 2017; Leman & Cinnirella, 2013; Basham, 2001), the need for making sense of high-impact events (Leman & Cinnirella, 2007; van Prooijen & van Dijk, 2014), and the need for clear agency (K. M. Douglas, Sutton, Callan, Dawtry, & Harvey, 2016), are not pathologies, but rather forms of cognitive heuristics, or cognitive biases.

1.1 | Hypotheses

Cognitive biases are systematic errors in human cognition that often arise in situations in which we need to subjectively assess probabilities, either explicitly or implicitly (Tversky & Kahneman, 1974). It has been suggested that conspiratorial thinking is a coping mechanism for uncertainty (Franks, Bangerter, & Bauer, 2013), but, even though there is some evidence that conspiratorial thinking is linked to errors in probabilistic thinking (Brotherton & French, 2014; Dagnall, Denovan, Drinkwater, Parker, & Clough, 2017), the specific hypothesis of conspiratorial thinking as a heuristic for coping with uncertainty has not yet been put to the empirical test. We fill this gap with five experiments that test the following hypothesis: *The lower the probability of an event, the stronger the belief in a conspiratorial explanation of the event, and the weaker the belief in the common explanation of the event.*

In addition to our main hypothesis, we include two potential mediating factors in our experiments. As mentioned in the previous section, there is some evidence that conspiratorial reasoning might be more prominent when the events in question are of higher impact for society (Leman & Cinnirella, 2007; van Prooijen & van Dijk, 2014). We include this mediating factor in our study and hypothesize that *belief in a conspiratorial explanation is stronger in a high-impact scenario than in a low-impact scenario*. We define a low-impact event as an event that does not affect society as a whole, but only a very small group of people.

A second potentially mediating factor is the clarity of a motive for conspirators to conspire. A prominent feature of conspiracy theories and conspiratorial arguments is intentionality, or the presence of an ulterior, yet clear motive (Uscinski & Parent, 2014, p. 43). We include the presence of a clear ulterior motive as a potential mediating factor in our study and hypothesize that *belief in a conspiratorial explanation is stronger in a scenario with a clear ulterior motive.*

2 | DESIGN, DATA, METHODS

2.1 | Five experiments

We test one main and two auxiliary hypotheses, as described in the previous section. In order to do so adequately, we conducted five separate experiments. The first of those experiments was designed to simply test the impact of event probabilities. Experiments two and three test the impact of event probabilities, and in addition, they are low-impact events either without a clear ulterior motive (experiment two) or with a clear ulterior motive (experiment three). Experiments four and five test the impact of event probabilities, and in addition, they are high-impact events either without a clear ulterior motive (experiment four) or with a clear ulterior motive (experiment five)

2.2 | Recruitment of participants

Participants for the experiments presented in this paper were recruited on the crowdsourcing platform Clickworker (Lutz, 2015). Each participant was remunerated with €0.15 for completing a short survey that was the experiment. All five experiments were designed to take around 1 min to complete. The experiments were conducted with version 2.63.1 of the open-source survey software LimeSurvey (LimeSurvey Project Team / Carsten Schmitz, 2012).

For experiment one (two experimental groups), we commissioned 250 surveys, and for experiments two to five (five experimental groups), 500 surveys per experiment. Our goal was to have, on average, 100 participants per experimental condition. For experiment one, we over-recruited experiment participants, because it was not entirely clear whether only completed surveys were considered part of the commissioned quota or whether incomplete surveys also counted towards it. When it became obvious during experiment one that only completed surveys counted towards the commissioned quota, we decided not to overrecruit for experiments two and three. The numbers of completed surveys slightly diverge from the commissioned numbers. For experiment one, 244 instead of 250 surveys were completed; for experiment two, exactly 500; for experiment three, 504; for experiment four, 502; and for experiment five, 504. The crowdsourcing platform that we worked with thus has some imprecision in terms of commissioned versus completed surveys, but the differences are within a ±2.5% range.

2.3 | Design of experiment one: The lottery

We have conducted five experiments in order to test the impact of probabilistic information on conspiratorial reasoning. For experiment one, 244 participants (65% women, mean age = 34.8, *SD* = 11.9) were randomly assigned to two groups: 121 participants were assigned to the first group, and 123 participants were assigned to the second group. The participants in the first group were exposed to the following text:

```
John decides to buy a lottery ticket. In order to
win the jackpot,
John needs to choose 6 numbers correctly.
The next day, the lottery numbers are drawn: John
has 0 correct numbers.
Next week, John decides to buy a new lottery
ticket. When the new numbers
are drawn, John ends up with 0 correct numbers
again.
The statistical probability of ending up with 0
correct
numbers two weeks in a row is around 19%.
What do you think: How likely is it, from 0 (not
at all
likely) to 10 (very likely), that...
...John was simply unlucky?
...the lottery was manipulated?
```

The order of the two questions at the end was randomized. The participants in the second group were exposed to the following text:

```
John decides to buy a lottery ticket. In order to
win the jackpot, John needs to choose 6 numbers
correctly. The next day, the lottery numbers are
drawn: John has 6 correct numbers—he has won the
jackpot.
Next week, John decides to buy a new lottery
ticket. When the new numbers are drawn, John ends
up with 6 correct numbers—he has won the jackpot
again.
The statistical probability of ending up with
6 correct numbers two weeks in a row is around
0.0000000000005%.
What do you think: How likely is it, from 0 (not
at all likely) to 10 (very likely), that...
...John was simply lucky?
...the lottery was manipulated?
```

As in the first group, the order of the two questions at the end was randomized. After answering the questions about how likely they thought it was that John was (un-)lucky and how likely they thought it was that the lottery was manipulated, participants in both groups were asked to provide information on their gender, their age, and their country of residence. For the sake of simplicity, the gender options were female and male only. The probabilities of 19% in experiment one and 0.0000000000005% in experiment two are derived from a simple lottery setup with 49 numbers in total.

2.4 | Design of experiment two: Falling roof tile (low impact, lack of clear ulterior motive)

For experiment two, 500 participants (64% women, mean age = 34.2, *SD* = 12.1) were randomly assigned to five groups: 82 participants were assigned to the first group, 105 to the second group, 101 to the third group, 108 to the fourth group, and 104 to the fifth group. The participants in all groups were exposed to a nearly identical text. The only difference, marked here as `XX%`, was the probabilistic information that each group received about the event in question:

```
John is walking down the street. It's a windy day.
As he is walking, a roof tile suddenly hits John on the head.
According to roofers (experts in roof tiles), the probability that a roof tile comes loose on a windy day is XX%.
What do you think: How likely is it, from 0 (not at all likely) to 10 (very likely), that...
...the tile hit John by accident?
...someone dropped the tile on John's head on purpose?
```

The order of the two questions was randomized. In the text for the first group, the probability of a roof tile coming loose was presented to be 1%. In the second group, that probability was 25%; in the third group, it was 50%; in the fourth group, it was 75%; in the fifth group, it was 99%. As in experiment one, participants in both groups were asked to provide information on their gender, their age, and their country of residence upon answering the two questions about the common and the conspiratorial explanation. For the sake of simplicity, the gender options were female and male only.

Experiment two is a low-impact scenario (John being hit on the head is not of general concern for society), and the story lacks a clear ulterior motive.

2.5 | Design of experiment three: Falling roof tile (low impact, clear ulterior motive)

For experiment three, 504 participants (61% women, mean age = 33.4, *SD* = 12.2) were randomly assigned to five groups: 101 participants were assigned to the first group, 91 to the second group, 103 to the third group, 108 to the fourth group, and 101 to the fifth group. As in experiment two, participants in all groups were exposed to a nearly identical text. The only difference, marked here as `XX%`, was the probabilistic information that each group received about the event in question:

```
John has recently broken up with his girlfriend. His girlfriend was very angry when John broke up with her.
One windy day, John is walking down the street. A man stops John and asks him for directions. While John is explaining the directions to the man, a roof tile suddenly hits John on the head.
According to roofers (experts in roof tiles), the probability that a roof tile comes loose on a windy day is XX%.
What do you think: How likely is it, from 0 (not at all likely) to 10 (very likely), that...
...the tile hit John by accident?
...the man who stopped John did so on purpose so that John's ex-girlfriend could attack John with the roof tile?
```

The order of the two questions was randomized. The probabilistic information for the five groups is the same as in experiment two. As in experiments one and two, participants in both groups were asked to provide information on their gender, their age, and their country of residence upon answering the two questions about the common and the conspiratorial explanation. For the sake of simplicity, the gender options were female and male only.

Experiment three is a low-impact scenario (John being hit on the head is not of general concern for society), just as experiment two. However, experiment three contains a clear ulterior motive.

2.6 | Design of experiment four: Deceased journalist (high impact, lack of clear ulterior motive)

For experiment four, 504 participants (63% women, mean age = 33.4, *SD* = 12.0) were randomly assigned to five different groups: 90 participants were assigned to the first group, 105 to the second group, 90 to the third group, 96 to the fourth group, and 123 to the fifth group. Much as in experiments two and three, the participants in all groups of experiment three were exposed to a nearly identical text. The only difference, marked as `XX%`, was the probabilistic information that each group received:

```
John is an accomplished journalist. He is found dead in his apartment: He died of a heart attack, officials declared.
According to doctors, the probability that someone like John dies of a heart attack is XX%.
What do you think: How likely is it, from 0 (not at all likely) to 10 (very likely), that...
...John really suffered a heart attack?
...John did not really suffer a heart attack, but that he was actually murdered?
```

The order of the two questions was randomized. In the text for the first group, the probability of "someone like John" to die of a heart attack was presented to be 1%. The second group, that probability was 25%; in the third group, it was 50%; in the fourth group, it was 75%; in the fifth group, it was 99%. As in experiments one, two, and three, participants in both groups were asked to provide information on their gender, their age, and their country of residence upon answering the two questions about the common and the conspiratorial explanation. For the sake of simplicity, the gender options were female and male only.

Experiment four is a scenario with a high-impact story, the death and potential murder of a journalist, but there is no clear ulterior motive provided in the story.

2.7 | Design of experiment five: Deceased journalist (high impact, clear ulterior motive)

For experiment five, 502 participants (64% women, mean age = 34.0, *SD* = 12.1) were randomly assigned to five different groups: 103 participants were assigned to the first group, 99 to the second group, 91 to the third group, 124 to the fourth group, and 85 to the fifth group. Once again, the participants in all groups of experiment five were exposed to a nearly identical text. The only difference, marked as `XX%`, was the probabilistic information that each group received:

```
John is an accomplished journalist who is criti-
cal of the government. He has just published an
article where he exposed a big corruption scandal
in the government.
A day after the article has been published, John
is found dead in his apartment: He died of a
heart attack, officials declared.
According to doctors, the probability that some-
one like John dies of a heart attack is XX%.
What do you think: How likely is it, from 0 (not
at all likely) to 10 (very likely), that...
...John really suffered a heart attack?
...John did not really suffer a heart attack, but
that he was actually murdered by the government?
```

The order of the two questions was randomized. The probabilistic information for the five groups is the same as in experiment four. As in experiments one to four, participants in both groups were asked to provide information on their gender, their age, and their country of residence upon answering the two questions about the common and the conspiratorial explanation. For the sake of simplicity, the gender options were female and male only.

Experiment five is a scenario with a high-impact story, the death and potential murder of a journalist, in combination with a clear motive, the government silencing a prominent critic.

2.8 | Data analysis and researcher degrees of freedom

In any empirical scientific context, so-called researcher degrees of freedom (Simmons, Nelson, & Simonsohn, 2011) are a challenge. Researcher degrees of freedom describe the fact that between the start of the data collection and the reporting of results, researchers can make and have to make many decisions that determine the final reported results. Unfortunately, many of those decisions are not made a priori, but rather during and after the collection of the data. The general problem with researcher degrees of freedom is that researchers have intrinsic and extrinsic incentives to engage in so-called data dredging (Smith & Ebrahim, 2002) and *p*-hacking (Head, Holman, Lanfear, Kahn, & Jennions, 2015), and even in HARKing (Kerr,(1998); hypothesizing after the results are known). *p*-Hacking and HARKing are (at the very least) borderline unethical, but the problem of research degrees of freedom is present event when researchers do not actively and knowingly engage in practices such as *p*-hacking (Gelman & Loken, 2013).

In our analysis, we have actively sought to minimize researcher degrees of freedom and, where degrees of freedom are present, to make rational decisions. Researcher degrees of freedom in our three experiments pertain to three dimensions: experiment design, data preparation, and data analysis.

In terms of *experiment design*, we have made the conscious decision to limit the data collected in the three experiment to precisely the data that is reported: The answers to the two main questions, and, in addition, information on participants' gender, age, and country of residence. We did not collect any additional data—the studies reported here are not, for example, only one part of a larger data set that will be used for additional publications.

In terms of *data preparation*, we have included all completed surveys into our data analyses. We did not exclude any cases.

In terms of *data analysis*, we have made two decisions. First, we are only looking at what is sometimes referred to as “main effects”: We did not estimate any form of interaction effects, and we did not partition data into gender, age, or any other kind of subgroups. We are simply estimating the data in its most direct form, because that is what we are interested in given our hypothesis. Furthermore, rather than engage in frequentist “significance testing,” we are estimating means with the help of Bayesian estimation. Epistemologically, Bayesian estimation is attractive because it is a quantification of uncertainty that does not rely on a test statistic. The models we estimate are all of the following form:

$$y \sim t(\mu, \sigma, \nu)$$

$$\mu \sim \mathcal{N}(5, 5)$$

$$\sigma \sim Cauchy(0, 2)$$

$$\nu \sim Gamma(2, 0.1).$$

The models are estimated using the probabilistic modeling environment Stan (Carpenter et al. 2017) from within the statistical environment R (R Core Team, 2017). The modeling approach we use is a generalized version of a “robust” estimation of means whereby the Student's *t* distribution is used as the sampling distribution (Kruschke, 2013; Lange, Little, & Taylor, 1989). The models were estimated by running 4,000 warmup and 4,000 sampling iterations with three chains. The estimates converged well, as indicated by potential scale reduction factors (Gelman & Rubin, 1992) of $\hat{R} = 1$.

The model contains three parameters that are specified with priors; these priors represent researcher degrees of freedom. We have specified the prior for the mean μ as a normal distribution with mean 5 and standard deviation 5. Given the scale of the data *y* (0 - 10), the prior for μ is a rather simple very broad prior. The second parameter in the model, σ, is modeled as a half-Cauchy distribution (a Cauchy distribution truncated at 0) with scale 2. The half-Cauchy prior is a vaguely informative prior recommended for variance parameters (Polson & Scott, 2012). Finally, the normality parameter ν that governs the heaviness of the

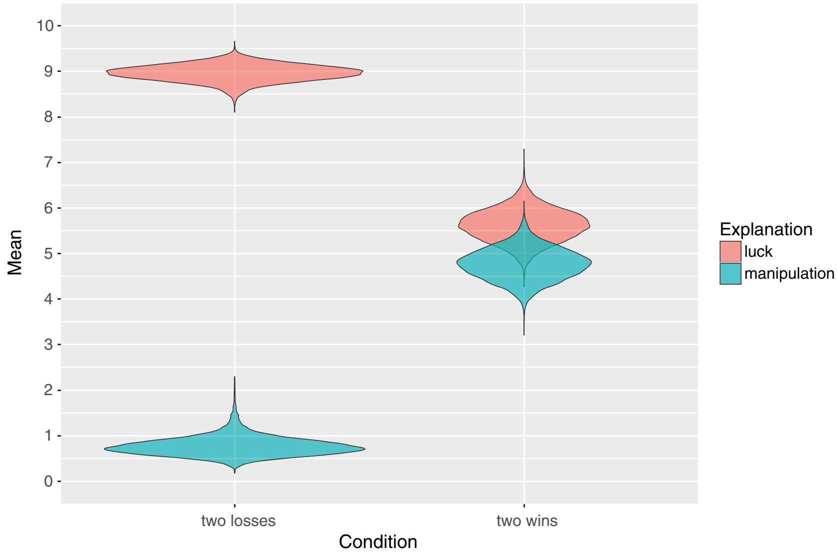


FIGURE 1 Estimated means for the responses in the two groups (conditions) of experiment one. The estimates for the common explanation are red, and the estimates for the conspiratorial explanation are blue [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Summary of the parameter estimates of experiment one

Parameter	Condition	Explanation	Mean	2.5%	97.5%	$\hat{R}$
μ	Two losses	Common	8.96	8.58	9.3	1
σ	Two losses	Common	1.27	0.96	1.66	1
ν	Two losses	Common	1.97	1.25	3.17	1
μ	Two losses	Conspiratorial	0.77	0.44	1.29	1
σ	Two losses	Conspiratorial	1.15	0.79	1.77	1
ν	Two losses	Conspiratorial	1.62	1.05	3.09	1
μ	Two wins	Common	5.62	4.94	6.31	1
σ	Two wins	Common	3.69	3.25	4.2	1
ν	Two wins	Common	34.95	12.81	73.81	1
μ	Two wins	Conspiratorial	4.77	4.1	5.43	1
σ	Two wins	Conspiratorial	3.64	3.21	4.15	1
ν	Two wins	Conspiratorial	35.22	12.9	73.86	1

tails in the *t* distribution is modeled as a Gamma distribution with shape 2 and scale 0.1, which represents a vaguely informative prior (Juárez & Steel, 2010). The Bayesian modeling approach, then, does introduce additional researcher degrees of freedom, but because we are using the same specifications for all models, this means that we are not, for example, arbitrarily changing priors in order to create results that fit our hypothesis. Furthermore, we are consistently using vague priors, meaning that the data has much greater say than the likelihood. A practical benefit of the Bayesian approach is that it eliminates incentives for *p*-hacking: There are no *p* values, and, therefore, there are no "significant" or "not significant" results in the sense of rules of thumb such as $p < 0.05$ equals "statistically significant."

We have sought to minimize researcher degrees of freedom and to make rational decisions in those degrees of freedom that are present in our data analysis. In addition, all of our raw, unaltered data will be made available via the Open Science Framework.

3 | RESULTS

3.1 | Experiment one: The lottery

The estimation results for experiment one are summarized in Figure 1.

The violin plots in Figure 1 are visualizations of the posterior distribution of the estimated means for the two questions in each group. As can be plainly seen from Figure 1, the estimated means for the two groups are very different. The group that was exposed to the story about John losing twice very strongly believes in the common explanation (luck), and only very weakly in the conspiratorial explanation (manipulation). The situation is quite different in the group that read about John winning twice: The estimated means are very close to each other. The belief in the conspiratorial explanation (manipulation) is much stronger than is the case in the first group; so much so that there is no overlap between the posterior distribution for the conspiratorial explanation (manipulation) between the groups. This means that the true mean is almost certainly lower in the first, (relatively) high probability group (John losing twice) than in the second, low probability group (John winning twice). The same is true for the means of the common explanation (luck): The posterior distributions of the means of the two groups do not overlap, and, therefore, the real mean is almost certainly higher in the first group than in the second group.

The parameter estimates for experiment one are summarized in tabular form in Table 1.

3.2 | Experiment two: Falling roof tile (low impact, lack of clear ulterior motive)

The results of the estimates for experiment two are summarized in Figure 2.

The participants in all five groups clearly believe that the common explanation is much more probable than the conspiratorial one. However, the trend of the means for both explanations is one consistent with our hypothesis: The lower the alleged probability of the event, the

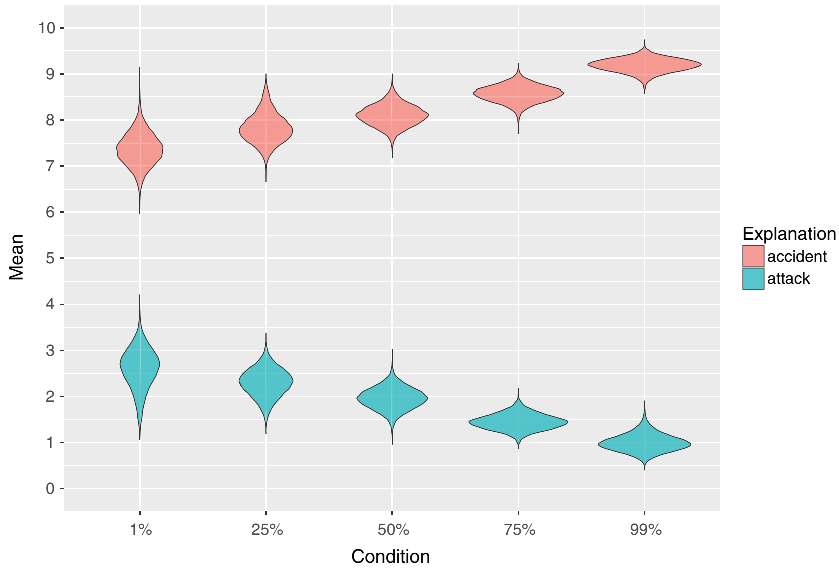


FIGURE 2 Estimated means for the responses in the five groups (conditions) of experiment two. The estimates for the common explanation are red, and the estimates for the conspiratorial explanation are blue [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 2 Summary of the parameter estimates for the common explanation in experiment two

Parameter	Condition (%)	Explanation	Mean	2.5%	97.5%	$\hat{R}$
μ	1	Common	7.37	6.67	8.08	1
σ	1	Common	2.78	2.24	3.33	1
ν	1	Common	22.52	4.43	58.35	1
μ	25	Common	7.83	7.25	8.55	1
σ	25	Common	2.3	1.51	2.79	1
ν	25	Common	18.47	2.2	53.79	1
μ	50	Common	8.1	7.66	8.56	1
σ	50	Common	1.94	1.57	2.31	1
ν	50	Common	17.63	4.02	49.07	1
μ	75	Common	8.57	8.21	8.91	1
σ	75	Common	1.37	1.05	1.76	1
ν	75	Common	3.98	1.91	8.95	1
μ	99	Common	9.19	8.88	9.46	1
σ	99	Common	1	0.74	1.34	1
ν	99	Common	1.99	1.22	3.34	1

TABLE 3 Summary of the parameter estimates for the conspiratorial explanation in experiment two

Parameter	Condition (%)	Explanation	Mean	2.5%	97.5%	$\hat{R}$
μ	1	Conspiratorial	2.6	1.6	3.38	1
σ	1	Conspiratorial	2.64	1.59	3.32	1
ν	1	Conspiratorial	17.68	1.87	53.15	1
μ	25	Conspiratorial	2.29	1.67	2.87	1
σ	25	Conspiratorial	2.17	1.5	2.67	1
ν	25	Conspiratorial	15.09	2.34	48.88	1
μ	50	Conspiratorial	1.96	1.49	2.41	1
σ	50	Conspiratorial	2.01	1.62	2.39	1
ν	50	Conspiratorial	18.65	4.23	50.42	1
μ	75	Conspiratorial	1.45	1.13	1.79	1
σ	75	Conspiratorial	1.25	0.93	1.6	1
ν	75	Conspiratorial	3.15	1.62	6.05	1
μ	99	Conspiratorial	1	0.66	1.41	1
σ	99	Conspiratorial	1.19	0.83	1.64	1
ν	99	Conspiratorial	2.19	1.23	4.23	1

higher, on average, the belief in the conspiratorial explanation (attack), and the lower the belief in the common explanation (accident). There is some overlap of the distributions of the 1% and of the 99% groups for both questions. This means that it is possible that the true trend of the means between the very low probability and the very high probability group is, in fact, flat or even opposite from what it appears to be visually. Because the distributions in Figure 2 are empirical in nature, we can quantify that probability. The probability that the means of the 1% and 99% groups for the common explanation (accident) lie within the band of overlapping areas is 0.18, and the probability that the trend of the two means, were they to lie in that band of overlapping areas, is either flat or negative is 0.09. Similarly, the probability that the means of the 1% and 99% groups for the conspiratorial explanation (attack) lie within the band of overlapping areas is 0.20, and the probability that the trend of the two means, were they to lie in within the band of overlapping areas, is either flat or negative is 0.03. Overall, then, the probability that the trends of the means between the very low probability and the very high probability group actually behave as hypothesized is high.

The parameter estimates for the common explanation in experiment two are summarized in tabular form in Table 2.

The parameter estimates for the conspiratorial explanation in experiment two are summarized in tabular form in Table 3.

3.3 | Experiment three: Falling roof tile (low impact, clear ulterior motive)

The results of the estimates for experiment three are summarized in Figure 3.

In comparison with the estimates for experiment two, the participants in experiment three have stronger beliefs in the conspiratorial

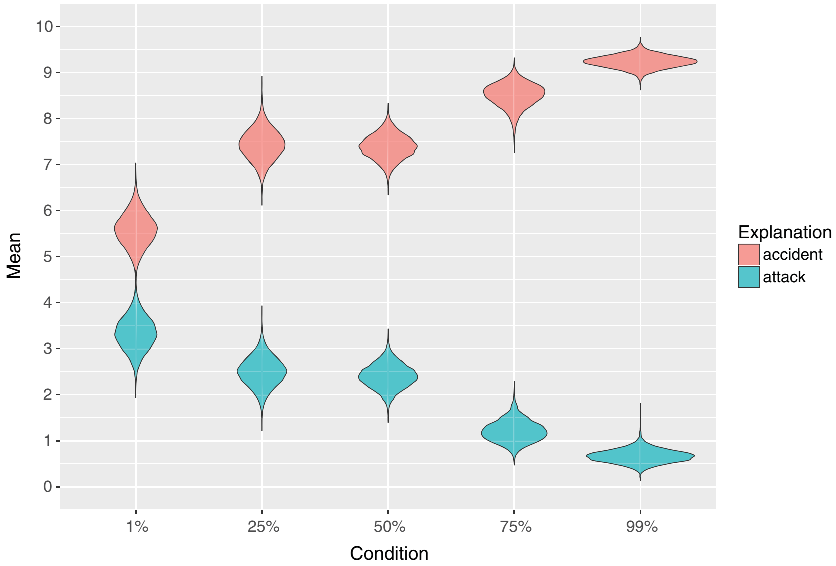


FIGURE 3 Estimated means for the responses in the five groups (conditions) of experiment three. The estimates for the common explanation are red, and the estimates for the conspiratorial explanation are blue [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 4 Summary of the parameter estimates for the common explanation in experiment three

Parameter	Condition (%)	Explanation	Mean	2.5%	97.5%	$\hat{R}$
μ	1	Common	5.59	4.88	6.31	1
σ	1	Common	3.53	3.06	4.06	1
ν	1	Common	33.28	11.7	72.28	1
μ	25	Common	7.43	6.77	8.09	1
σ	25	Common	2.9	2.45	3.41	1
ν	25	Common	26.53	6.81	63.49	1
μ	50	Common	7.39	6.86	7.91	1
σ	50	Common	2.4	2	2.83	1
ν	50	Common	21.55	5.32	54.66	1
μ	75	Common	8.51	7.93	8.95	1
σ	75	Common	1.62	1.16	2.32	1
ν	75	Common	3.44	1.5	10.47	1
μ	99	Common	9.24	8.96	9.5	1
σ	99	Common	0.96	0.72	1.24	1
ν	99	Common	1.53	1.08	2.25	1

TABLE 5 Summary of the parameter estimates for the conspiratorial explanation in experiment three

Parameter	Condition (%)	Explanation	Mean	2.5%	97.5%	$\hat{R}$
μ	1	Conspiratorial	3.33	2.63	4.04	1
σ	1	Conspiratorial	3.4	2.94	3.93	1
ν	1	Conspiratorial	31.18	9.89	69.97	1
μ	25	Conspiratorial	2.5	1.86	3.12	1
σ	25	Conspiratorial	2.78	2.36	3.26	1
ν	25	Conspiratorial	27.19	7.58	64.17	1
μ	50	Conspiratorial	2.4	1.89	2.92	1
σ	50	Conspiratorial	2.45	2.06	2.85	1
ν	50	Conspiratorial	24.48	6.17	59.99	1
μ	75	Conspiratorial	1.21	0.8	1.72	1
σ	75	Conspiratorial	1.48	1.06	2.01	1
ν	75	Conspiratorial	4.35	1.69	14.51	1
μ	99	Conspiratorial	0.67	0.4	0.97	1
σ	99	Conspiratorial	0.95	0.7	1.3	1
ν	99	Conspiratorial	1.38	1.02	2.04	1

explanation when presented with lower alleged probabilities. The difference in results between experiments two and three suggests that the presence of a clear ulterior motive has, ex expected, a mediating effect on conspiratorial belief. The overall trend of the estimated between conditions is not as smooth as in experiment two. However, neither the estimated distribution for the common nor for the conspiratorial explanation has any overlap between the 1% and the 99% groups, which suggests that the real trend of the means is as predicted between the very low probability and the very high probability groups.

The parameter estimates for the common explanation in experiment three are summarized in tabular form in Table 4.

The parameter estimates for the conspiratorial explanation in experiment three are summarized in tabular form in Table 5.

3.4 | Experiment four: Deceased journalist (high impact, lack of clear ulterior motive)

The results of the estimates for experiment four are summarized in Figure 4.

The trends for the estimated means of the belief in the common explanation (heart attack) and for the conspiratorial explanation (murder) in experiment four follow the pattern as predicted by our main hypothesis: The lower the alleged probability of the event, the stronger the belief in a conspiratorial explanation and the weaker the belief in the common explanation. As there is no overlap between the distributions of the 1% and the 99% groups, neither for the conspiratorial nor for the common explanation, the true trend between these two means cannot be flat or negative. In comparison to experiments two and three, the belief in the conspiratorial explanation is notably stronger (in the

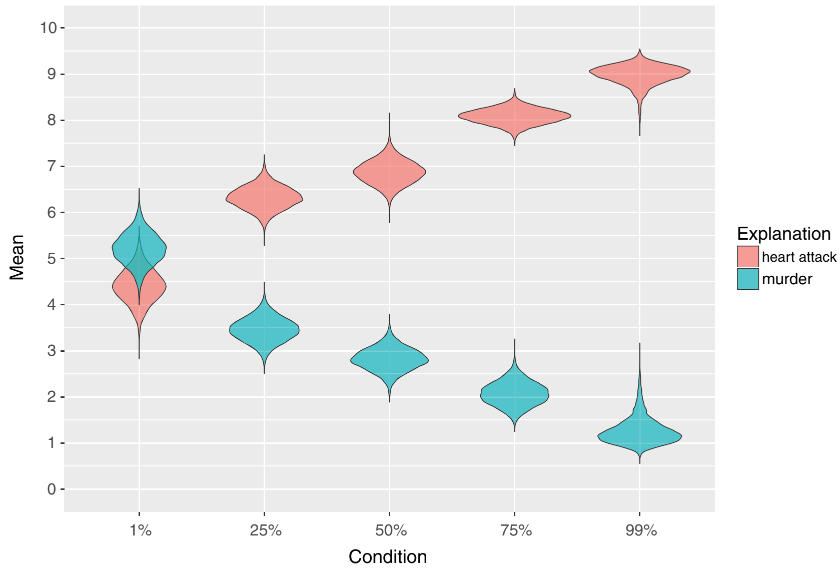


FIGURE 4 Estimated means for the responses in the five groups (conditions) of experiment four. The estimates for the common explanation are red, and the estimates for the conspiratorial explanation are blue [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 6 Summary of the parameter estimates for the common explanation in experiment four

	Condition (%)	Explanation	Mean	2.5%	97.5%	$\hat{R}$
μ	1	Common	4.4	3.69	5.13	1
σ	1	Common	3.25	2.8	3.79	1
ν	1	Common	30.87	9.92	68.22	1
μ	25	Common	6.32	5.84	6.8	1
σ	25	Common	2.38	2.05	2.75	1
ν	25	Common	28.02	8.51	65.07	1
μ	50	Common	6.87	6.37	7.38	1
σ	50	Common	2.28	1.94	2.69	1
ν	50	Common	24.29	6.62	59.59	1
μ	75	Common	8.08	7.76	8.4	1
σ	75	Common	1.47	1.21	1.75	1
ν	75	Common	18.65	4.55	51.09	1
μ	99	Common	8.98	8.45	9.32	1
σ	99	Common	1.24	0.85	1.89	1
ν	99	Common	1.92	1.09	4.19	1

TABLE 7 Summary of the parameter estimates for the conspiratorial explanation in experiment four

	Condition (%)	Explanation	Mean	2.5%	97.5%	$\hat{R}$
μ	1	Conspiratorial	5.21	4.53	5.9	1
σ	1	Conspiratorial	3.11	2.68	3.62	1
ν	1	Conspiratorial	30.34	9.84	68.09	1
μ	25	Conspiratorial	3.46	2.94	3.97	1
σ	25	Conspiratorial	2.57	2.23	2.96	1
ν	25	Conspiratorial	27.93	8.7	64.55	1
μ	50	Conspiratorial	2.82	2.32	3.3	1
σ	50	Conspiratorial	2.2	1.88	2.58	1
ν	50	Conspiratorial	26.63	7.7	62.38	1
μ	75	Conspiratorial	2.07	1.6	2.57	1
σ	75	Conspiratorial	1.78	1.28	2.26	1
ν	75	Conspiratorial	9.97	2.29	36.23	1
μ	99	Conspiratorial	1.27	0.87	2.09	1
σ	99	Conspiratorial	1.39	0.88	2.39	1
ν	99	Conspiratorial	2.27	1.06	7.67	1

low probability groups). This lends support to the auxiliary hypothesis that a high-impact event increases the endorsment of conspiratorial explanations.

The parameter estimates for the common explanation in experiment four are summarized in tabular form in Table 6.

The parameter estimates for the conspiratorial explanation in experiment four are summarized in tabular form in Table 7.

3.5 | Experiment five: Deceased journalist (high impact, clear ulterior motive)

The results of the estimates for experiment three are summarized in Figure 5.

The overall trend of the estimated means once again follows the predicted pattern: The lower the alleged probability of the event, the stronger the belief in the conspiratorial and the weaker the belief in the common explanation. The estimated means of the 1% and the 99% groups partly overlap. Although there is no overlap for the common explanation, there is some overlap for the conspiratorial explanation. The probability that the means lie in this band of area overlap is 0.19, and the probability that the trend of the means, were they to actually lie in that band of area overlap, is flat or positive is 0.01. It is therefore highly probable that the real trend of the means is negative. In comparison with the estimation results for experiment four, the overall belief in the conspiratorial explanation is much stronger. This lends further support to the auxiliary hypothesis that a clear ulterior motive increases the endorsement of conspiratorial beliefs. Within experiments two to five, the levels of conspiratorial belief are strongest in experiment five. This suggests that, as expected, conspiratorial beliefs are strongest in a high-impact, clear ulterior motive scenario.

The parameter estimates for the common explanation in experiment five are summarized in tabular form in Table 8.

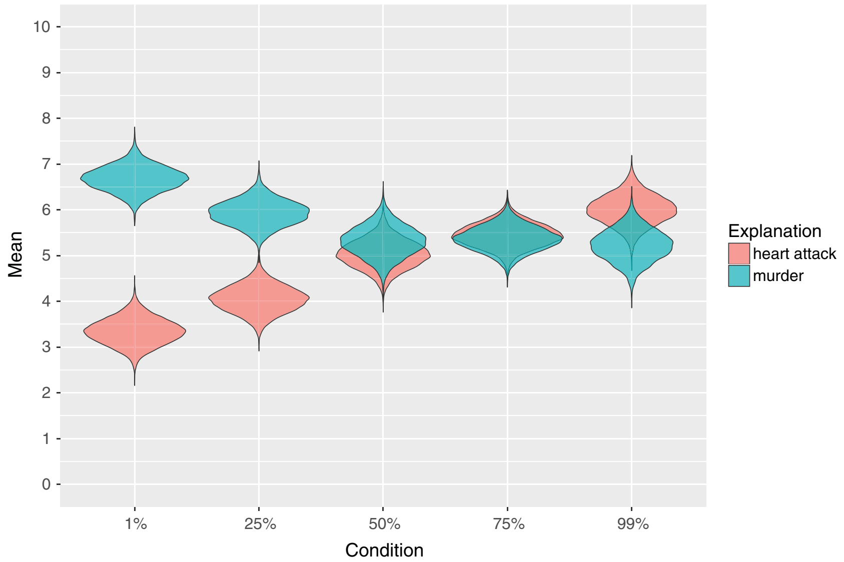


FIGURE 5 Estimated means for the responses in the five groups (conditions) of experiment five. The estimates for the common explanation are red, and the estimates for the conspiratorial explanation are blue [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 8 Summary of the parameter estimates for the common explanation in experiment five

	Condition (%)	Explanation	Mean	2.5%	97.5%	$\hat{R}$
μ	1	Common	3.34	2.79	3.91	1
σ	1	Common	2.74	2.35	3.19	1
ν	1	Common	26.99	7.73	62.75	1
μ	25	Common	4.05	3.48	4.63	1
σ	25	Common	2.79	2.4	3.24	1
ν	25	Common	29.19	8.85	66.15	1
μ	50	Common	5.02	4.4	5.65	1
σ	50	Common	2.87	2.46	3.36	1
ν	50	Common	28.62	8.58	66	1
μ	75	Common	5.45	4.93	5.96	1
σ	75	Common	2.79	2.43	3.19	1
ν	75	Common	31.21	10.06	70.36	1
μ	99	Common	6	5.36	6.64	1
σ	99	Common	2.83	2.41	3.34	1
ν	99	Common	28.03	7.97	65.05	1

TABLE 9 Summary of the parameter estimates for the conspiratorial explanation in experiment five

	Condition (%)	Explanation	Mean	2.5%	97.5%	$\hat{R}$
μ	1	Conspiratorial	6.68	6.15	7.23	1
σ	1	Conspiratorial	2.61	2.23	3.04	1
ν	1	Conspiratorial	26.26	7.32	62.6	1
μ	25	Conspiratorial	5.93	5.38	6.48	1
σ	25	Conspiratorial	2.69	2.31	3.13	1
ν	25	Conspiratorial	28.82	8.87	64.64	1
μ	50	Conspiratorial	5.32	4.65	5.98	1
σ	50	Conspiratorial	3.06	2.63	3.58	1
ν	50	Conspiratorial	30.14	9.6	67.13	1
μ	75	Conspiratorial	5.36	4.82	5.89	1
σ	75	Conspiratorial	2.87	2.52	3.27	1
ν	75	Conspiratorial	32.41	11.22	69.32	1
μ	99	Conspiratorial	4.54	5.89	5.89	1
σ	99	Conspiratorial	2.62	3.6	3.6	1
ν	99	Conspiratorial	9.74	67.4	67.4	1

The parameter estimates for the conspiratorial explanation in experiment five are summarized in tabular form in Table 9.

4 | DISCUSSION

4.1 | Limitations of this study

Besides the general limitations of any singular study (the main hypothesis needs to be further explored and the experiments replicated), we suspect that the framing of our experiments biased participants' responses. More specifically, we have presented the alleged probabilities for events as Pr(*event*|*chance*). The participants were asked to estimate Pr(*chance*|*event*) and Pr(*conspiracy*|*event*). It is possible that some or even all participants have simply interpreted Pr(*event*|*chance*) as Pr(*chance*|*event*) and Pr(*conspiracy*|*event*) as 1 − Pr(*event*|*chance*). Even though both of those deductions are incorrect, the framing of the experiments might have nudged the participants towards such an interpretation. Future research on the relationship between probability and conspiratorial thinking should therefore be designed in a way that avoids this potential bias.

4.2 | Conspiratorial thinking as a possible cognitive heuristic

Overall, the five experiments lend support to the hypothesis we set out to test: The lower the probability of an event, the stronger the belief in a conspiratorial explanation, and the weaker the belief in the common explanation. In addition, the results suggest that high-impact scenarios and scenarios with clear ulterior motives induce stronger belief in conspiratorial explanations. These results are not all that surprising in light of what is known about how humans handle probabilities: A number of cognitive biases are, in essence, errors in probabilistic thinking, and conspiratorial reasoning might represent just another such bias. For example, we know that humans tend to have a difficult time with handling low probability events, especially if the events in question have both low probability and high impact; this trait is sometimes described with the black swan metaphor (Taleb, 2010; Wardman & Mythen, 2016). In this context, conspiratorial thinking as a potential cognitive bias might represent a general strategy for handling probabilistic information, or, expressed more generally, a coping strategy for uncertainty, because probability is a quantification of uncertainty.

If conspiratorial thinking occurs as a general cognitive bias and not only as a pathology of the mind, which means that it might also be possible to devise countermeasures against conspiratorial thinking that have an effect of generalized debiasing (Croskerry, Singhal, & Mamede, 2013; Lilienfeld, Ammirati, & Landfield, 2009). In order to tackle specific singular conspiracy theories, "debunking" them might work. In order to tackle conspiratorial thinking in general, metacognitive debiasing as a form of training in probabilistic thinking might be more effective.

ORCID

Marko Kovic http://orcid.org/0000-0001-5926-7365

REFERENCES

Barron, D., Morgan, K., Towell, T., Altemeyer, B., & Swami, V. (2014). Associations between schizotypy and belief in conspiracist ideation. *Personality and Individual Differences*, *70*, 156–159.

Basham, L. (2001). Living with the conspiracy. *The Philosophical Forum*, *32*(3), 265–280.

Bentall, R. P., Kinderman, P., & Kaney, S. (1994). The self, attributional processes and abnormal beliefs: Towards a model of persecutory delusions. *Behaviour Research and Therapy*, *32*(3), 331–341.

Boudry, M., & Braeckman, J. (2012). How convenient! The epistemic rationale of self-validating belief systems. *Philosophical Psychology*, *25*(3), 341–364.

Brotherton, R., & French, C. C. (2014). Belief in conspiracy theories and susceptibility to the conjunction fallacy. *Applied Cognitive Psychology*, *28*(2), 238–248.

Carpenter, B., Gelman, A., Hoffman, M., Lee, D., Goodrich, B., Betancourt, M., ..., & Riddell, A. (2017). Stan: A probabilistic programming language. *Journal of Statistical Software*, *76*(1), 1–32. bibtex: JSSv076i01.

Clarke, S. (2002). Conspiracy theories and conspiracy theorizing. *Philosophy of the Social Sciences*, *32*(2), 131–150.

Croskerry, P., Singhal, G., & Mamede, S. (2013). Cognitive debiasing 1: Origins of bias and theory of debiasing. *BMJ Quality & Safety*, *22*(Suppl 2), ii58–ii64.

Dagnall, N., Denovan, A., Drinkwater, K., Parker, A., & Clough, P. (2017). Statistical bias and endorsement of conspiracy theories. *Applied Cognitive Psychology*, *31*(4), 368–378.

Darwin, H., Neave, N., & Holmes, J. (2011). Belief in conspiracy theories. The role of paranormal belief, paranoid ideation and schizotypy. *Personality and Individual Differences*, *50*(8), 1289–1293.

Douglas, K., Sutton, R. M., Jolley, D., & Wood, M. J. (2015). The social, political, environmental and health-related consequences of conspiracy theories: Problems and potential solutions. In Bilewicz, M., Cichocka, A., & Soral, W. (Eds.), *The psychology of conspiracy*. Abingdon, Oxford, UK: Taylor and Francis.

Douglas, K. M., Sutton, R. M., Callan, M. J., Dawtry, R. J., & Harvey, A. J. (2016). Someone is pulling the strings: Hypersensitive agency detection and belief in conspiracy theories. *Thinking & Reasoning*, *22*(1), 57–77.

Franks, B., Bangerter, A., & Bauer, M. (2013). Conspiracy theories as quasi-religious mentality: An integrated account from cognitive science, social representations theory, and frame theory. *Frontiers in Psychology*, *4*, 1–12.

Gelman, A., & Loken, E. (2013). The garden of forking paths: Why multiple comparisons can be a problem, even when there is no "fishing expedition" or "p-hacking" and the research hypothesis was posited ahead of time. *Department of Statistics, Columbia University*.

Gelman, A., & Rubin, D. B. (1992). Inference from iterative simulation using multiple sequences. *Statistical Science*, *7*(4), 457–472.

Gettier, E. L. (1963). Is justified true belief knowledge?. *Analysis*, *23*(6), 121–123.

Head, M. L., Holman, L., Lanfear, R., Kahn, A. T., & Jennions, M. D. (2015). The extent and consequences of p-hacking in science. *PLOS Biology*, *13*(3), e1002106.

Jolley, D., & Douglas, K. M. (2014). The effects of anti-vaccine conspiracy theories on vaccination intentions. *PLOS ONE*, *9*(2), e89177.

Jolley, D., & Douglas, K. M. (2014). The social consequences of conspiracism: Exposure to conspiracy theories decreases intentions to engage in politics and to reduce one's carbon footprint. *British Journal of Psychology*, *105*(1), 35–56.

Juárez, M. A., & Steel, M. F. J. (2010). Model-based clustering of non-Gaussian panel data based on skew-t distributions. *Journal of Business & Economic Statistics*, *28*(1), 52–66.

Keeley, B. L. (1999). Of conspiracy theories. *The Journal of Philosophy*, *96*(3), 109–126.

Kerr, N. L. (1998). HARKing: Hypothesizing after the results are known. *Personality and Social Psychology Review*, *2*(3), 196–217.

Kruschke, J. K. (2013). Bayesian estimation supersedes the t test. *Journal of Experimental Psychology. General*, *142*(2), 573–603.

Lange, K., Little, R. J. A., & Taylor, J. (1989). Robust statistical modeling using the t-distribution. *eScholarship*, *84*, 881–896. http://escholarship.org/uc/item/27s1d3h7.

Leman, P. J, & Cinnirella, M. (2007). A major event has a major cause: Evidence for the role of heuristics in reasoning about conspiracy theories. *Social Psychology Review*, *9*, 18–28.

Leman, P. J., & Cinnirella, M. (2013). Beliefs in conspiracy theories and the need for cognitive closure. *Frontiers in Psychology*, *4*, 378.

Lilienfeld, S. O., Ammirati, R., & Landfield, K. (2009). Giving debiasing away: Can psychological research on correcting cognitive errors promote human welfare?. *Perspectives on Psychological Science*, *4*(4), 390–398.

LimeSurvey Project Team / Carsten Schmitz (2012). *LimeSurvey: An Open Source survey tool*. Hamburg, Germany: LimeSurvey Project. Retrieved from http://www.limesurvey.org.

Lutz, J. (2015). The validity of crowdsourcing data in studying anger and aggressive behavior. *Social Psychology*, *47*(1), 38–51.

Marchlewska, M., Cichocka, A., & Kossowska, M. (2017). Addicted to answers: Need for cognitive closure and the endorsement of conspiracy beliefs. *European Journal of Social Psychology*, *27*, 283–317.

Oliver, J. E., & Wood, T. (2014). Medical conspiracy theories and health behaviors in the United States. *JAMA Internal Medicine*, *174*(5), 817–818.

Oliver, J. E., & Wood, T. J. (2014). Conspiracy theories and the paranoid style(s) of mass opinion. *American Journal of Political Science*, *58*(4), 952–966.

Polson, N. G., & Scott, J. G. (2012). On the half-cauchy prior for a global scale parameter. *Bayesian Analysis*, *7*(4), 887–902.

Pritchard, D. (2004). Epistemic luck. *Journal of Philosophical Research*, *29*, 191–220.

R Core Team (2017). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/.

Simmons, J. P., Nelson, L. D., & Simonsohn, U. (2011). False-positive psychology: Undisclosed flexibility in data collection and analysis allows presenting anything as significant. *Psychological Science*, *22*(11), 1359–1366.

Smith, G. D., & Ebrahim, S. (2002). Data dredging, bias, or confounding. *BMJ : British Medical Journal*, *325*(7378), 1437–1438.

Sunstein, C. R., & Vermeule, A. (2009). Conspiracy theories: Causes and cures. *Journal of Political Philosophy*, *17*(2), 202–227.

Swami, V., Weis, L., Lay, A., Barron, D., & Furnham, A. (2016). Associations between belief in conspiracy theories and the maladaptive personality traits of the personality inventory for DSM-5. *Psychiatry Research*, *236*, 86–90.

Taleb, N. N. (2010). *The black swan: The impact of the highly improbable* (2nd ed.). New York: Random House Trade Paperbacks.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, *185*(4157), 1124–1131.

Uscinski, J. E., & Parent, J. M. (2014). *American conspiracy theories*. Oxford: Oxford University Press.

van Prooijen, J.-W., & van Dijk, E. (2014). When consequence size predicts belief in conspiracy theories: The moderating role of perspective taking. *Journal of Experimental Social Psychology*, *55*, 63–73.

Wardman, J. K., & Mythen, G. (2016). Risk communication: Against the Gods or against all odds? Problems and prospects of accounting for Black Swans. *Journal of Risk Research*, *19*(10), 1220–1230.

How to cite this article: Kovic M, Füchslin T. Probability and conspiratorial thinking. *Appl Cognit Psychol*. 2018;32:390–400. https://doi.org/10.1002/acp.3408

7.9 Metag et al. (2016)

Perceptions of Climate Change Imagery: Evoked Salience and Self-Efficacy in Germany, Switzerland, and Austria.

Metag, J., Schäfer, M. S., Füchslin, T., Barsuhn, T., & Kleinen-von Königslöw, K.

This article was originally published in:

Metag, J., Schäfer, M. S., Füchslin, T., Barsuhn, T., & Kleinen-von Königslöw, K. (2016). Perceptions of Climate Change Imagery. *Science Communication, 38*(2), 197–227. https://doi.org/10.1177/1075547016635181

Research Article

Science Communication
2016, Vol. 38(2) 197–227

DOI: 10.1177/1075547016635181
scx.sagepub.com
SAGE

Perceptions of Climate Change Imagery: Evoked Salience and Self-Efficacy in Germany, Switzerland, and Austria

Julia Metag[1], Mike S. Schäfer[1], Tobias Füchslin[1], Tjado Barsuhn[2], and Katharina Kleinen-von Königslöw[1]

Abstract

Prevalent in mass media worldwide, climate change imagery appears to be similar across countries. Replicating a study from the United States, United Kingdom, and Australia, we analyze whether these images are perceived in similar ways cross-nationally by studying Germany, Switzerland, and Austria. A total of 75 respondents sorted images with respect to their perceptions of salience and self-efficacy (Q method). They associated images of climate change impacts most strongly with salience, while they related imagery of renewable energies and mobility to self-efficacy. These findings suggest that perceptions of climate change visuals are largely consistent cross-culturally. They indicate that imagery that is frequently used in media is rarely associated with feelings of salience or self-efficacy.

Keywords

climate change, images, public perception of, Q methodology, visual communication

[1]University of Zurich, Zurich, Switzerland
[2]University of Hamburg, Hamburg, Germany

Corresponding Author:
Julia Metag, University of Zurich, Institute of Mass Communication and Media Research, Andreasstrasse 15, CH-8050 Zurich, Switzerland.
Email: j.metag@ipmz.uzh.ch

Introduction: The Significance of Climate Change Imagery

Inside the conference center, the 16th Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change was well under way; outside, a number of Greenpeace activists walked down to Cancun Beach. They had alerted journalists to come along, and a crowd gathered as they started to inflate a giant life ring with the nongovernmental organization's logo. The activists laid down to form the word "Hope" with their bodies, and cameras started clicking and filming, producing images that quickly appeared in media around the world, for example, in the British *Telegraph* and *Daily Mail* and in the NBC and BBC news.

When news media provide information and orientation about the transnational issue of climate change, they use visual images frequently and prominently (O'Neill & Smith, 2014). That some of these pictures, such as Greenpeace's "Hope" symbol during COP 16, are shared widely in international media is in line with studies showing that visual representations of climate change are similar in many countries. They often emphasize the threat of climate change impacts, focus on nature themes, visualize climate models, cover people (especially politicians), and visualize related themes such as energy issues (Grittmann, 2013; O'Neill, 2013; O'Neill & Smith, 2014; Schneider, 2012; Schneider & Nocke, 2014).

Little is known about the audience's perception of these images, however. Preliminary results indicate that they may also be similar across countries. O'Neill, Boykoff, Niemeyer, and Day (2013) have shown that perceptions of climate change imagery in the United States, United Kingdom, and Australia are quite consistent. Similar images increased audience members' perception of the importance (salience) of climate change in all three countries. Likewise, a different set of images—also similar across countries—promoted people's sense that they could do something about climate change (self-efficacy).

While there has been research on the domestication of media coverage on global issues in different national contexts, it has rarely been investigated whether perceptions of images differ cross-culturally in visual communication research. Therefore, it is unclear whether similar perceptions are limited to Anglophone countries—which are relatively homogenous when it comes to attitudes toward climate change and its media representations (cf. Schmidt, Ivanova, & Schäfer, 2013)—or whether these similarities extend to other regions of the world. The three largest German-speaking countries—Germany, Switzerland, and Austria—provide an excellent case for comparison in this respect, as they differ from the Anglo-American countries in several aspects: They are affected differently by climate change impacts

(DARA and the Climate Vulnerable Forum, 2012), have less coverage of global warming in the media (Peters & Heinrichs, 2008; Schmidt et al., 2013), and have lower levels of climate skepticism among their populations (Engels, Hüther, Schäfer, & Held, 2013) and in the media (Kaiser & Rhomberg, 2015; Schäfer, forthcoming). The question thus arises whether or not images of climate change are perceived differently in these countries.

In order to investigate whether there are cultural differences in how climate change imagery is perceived in different contexts, this article replicates O'Neill et al.'s (2013) study investigating perceptions of climate change images in Germany, Switzerland, and Austria. Using Q sorting research, it focuses on the kinds of visual representations of climate change that evoke perceptions of salience ("The image makes me feel that climate change is an important issue") and self-efficacy ("The image makes me feel that I can do something about climate change").

Studies on Climate Change Imagery: What Do We Know So Far?

A growing body of scholarly literature has analyzed prevalent climate change depictions in news media coverage, mainly taken from newspapers and magazines as well as television (for overviews, see Manzo, 2010a; O'Neill & Smith, 2014).

Visual Representations of Climate Change

Most studies employ content analysis to describe which images are used by the media to illustrate climate change. They focus on traditional news coverage such as the coverage of climate change in quality and tabloid newspapers and on television. Other mass media like radio, online content, or fictional and entertainment formats are rarely investigated (see Table 1 for an overview). Existing studies have established that five visual themes account for most of the climate change imagery used in news coverage:

- *Images of climate change impacts and threats*: One of the main themes in the visual discourse is climate change impacts, particularly disasters and risks (Rebich-Hespanha et al., 2015). Television news outlets in six countries—the United Kingdom, the United States, Australia, South Africa, India, and Singapore—focus on images that depict the environment and people as being threatened by climate change impacts (Lester & Cottle, 2009). The images used—rising sea levels and destructive weather events like floods—are spectacular and resonate

Table 1. Overview of Studies on Climate Change Imagery.

Author	Country, Timespan, Media/Sample	Method	Main Results with regard to *images themes*
DiFrancesco & Young, 2011	Canada; January 2008 - July 2008; National newspapers (The Globe and Mail; The National Post; n =375 content analysis; n = 100 in discourse analysis); search terms 'climate change' OR 'global warming' OR 'greenhouse effect', AND 'images', OR 'photos' OR 'illustrations'	Content analysis; critical discourse analysis	*people/ talking heads*: two-thirds of all images focus on one or more identifiable human beings
Doyle, 2007	UK; 1994 – 2007; Greenpeace UK-Publications and campaign material	Historical analysis	Study identifies five representational strategies/phases. *climate change impacts*: phase 2:o images on identifying causes and present impacts; phase 3: glacial impacts prominent; phase 5: images that represent "The 'Here and Now' of Climate Change" *carbon emissions/ energy issues*: phase 3: renewable solutions; phase 4: images such as dirty oil
Eide, 2012	Copenhagen climate summit 2009 (15 countries); One elite and one popular newspaper in each country; N=2348 (overall)	Quantitative analysis; Frame analysis	*people/ talking heads*: Largest category of images is pictures of persons
Grittmann, 2013, 2014	Germany; November 15 -December 23, 2009; Three quality newspapers (die tageszeitung, Süddeutsche Zeitung, Welt); a tabloid (BILD); news magazines (Spiegel, Stern); a weekly newspaper (Die Zeit); monthly reportage magazine (GEO); search terms: climate conference, climate conference participant, climate protection, climate change	Qualitative Framing analysis	*climate change impacts*: images of disasters like flooding, hurricanes and drought are used to depict problem definitions *carbon emissions/ energy issues*: pictures of power plants, traffic, deforestation and meat production are used to exemplify causes

(continued)

Table 1. (continued)

Author	Country, Timespan, Media/Sample	Method	Main Results with regard to *images themes*
Hoijer, 2010	Sweden; November 2006 (*Aftonbladet*), 7-19 October 2005 (*Rapport*); tabloid press (Aftonbladet); television public service news programme (Rapport); n=75 news items (overall)	Qualitative content analysis; open coding	*climate change impacts*: images representing fear, hope, guilt, compassion (e.g. pictures of cute and innocent animals) and nostalgia
Lester & Cottle, 2009	UK, USA, Australia, South Africa, India, and Singapore; September 13 - 26, 2004; Television News (daily and high-rating news programs), Satellite TV broadcasters (BBC World, CNN International, Fox News, and Sky News Australia); n= 27 news stories	Not specified, likely quantitative content analysis	*climate change impacts*: visualizations of environments and people as under threat, deploying spectacular and culturally resonant images *people/ talking heads*: visualized scientists and politicians
Manzo, 2010a	UK; no specific time span; "Newspapers in particular" and suitable worldwide evidence (no further specification)	Overview of other academic studies	Study identifies different image frames. *nature themes*: wildlife frame: polar bears as icons of global warming *climate change impacts/ people*: justice and equity frame: images of the global poor as victims of climate change; extreme weather frame: images of global warming and the effects of climate change *carbon emissions/ energy issues*: icons of renewable energy
Manzo, 2010b	UK; 2007 – 2008; Images used in UK climate action campaigns (no further specification)	Semiotic analysis of meaning	*nature themes*: pictures of danger and vulnerability; iconographic images of disaster
O'Neill, 2013	USA, UK, Australia; 2010; Online articles from 13 newspapers; n=1603 (overall)	Content analysis; Frame analysis	*climate change impact & people/ talking heads*: People, impact and protest images most frequent

(continued)

Table 1. (continued)

Author	Country, Timespan, Media/Sample	Method	Main Results with regard to *images themes*
Rebich-Hespanha et al., 2015	USA; 1969-2009; Newspaper and magazine stories in 11 US news source archives; n = 350 images	Manifest coding of objective characteristics, qualitative content analysis to identify themes, cluster analysis to identify frames	Frames with *climate change impacts*: impacts on polar animals and landscapes; "Regular" people affected by climate change; storms frame Frames with *nature themes*: future climate, vulnerable landscapes, and adaptation frame; wilderness and nature recreation frame Frames with *people/ talking heads*: government, politics, and negotiation frame; "Regular" people affected by climate change; citizen leaders frame Frames with *carbon emissions/ energy issues*: food and agriculture frame; alternative energy and energy prices frame
Rüegg, 2015	Germany, Switzerland, Austria; 2014 (partly 2013); Online outlets of German (FAZ.net, Sueddeutsche.de, Bild.de), Swiss (NZZ.ch, Tagesanzeiger.ch, Blick.ch) and Austrian (Diepresse.com, Derstandard.at, Krone.at) quality and tabloid newspapers; search term: 'climate change '	Quantitative content analysis, qualitative frame analysis	*climate change impacts*: impacts of climate change as second most frequent image theme (15.4%) *nature themes*: nature and landscapes as third most frequent image theme (12.5%) *people/ talking heads*: people are most frequent image theme in each country (20.2%) *Graphs and models*: 6.7% of the images are graphs
Schneider, 2012	Germany; 2007; Exemplary case study of visualizations of future temperature variations produced by the German Climate Computing Centre (DKRZ)	overview on visualization of climate model data simulation	*Graphs and models*: visualizations derived from climate model simulations as best-known image types produced by climate science

(continued)

Table 1. (continued)

Author	Country, Timespan, Media/Sample	Method	Main Results with regard to *images themes*
Slocum, 2004	Canada, USA; no specific time span; Cities for Climate Protection (CCP) campaign and Greenpeace Canada's (GPC) climate campaign	147 interviews with campaign contacts	Identifies different "boundary objects" used in campaigns: *nature themes*: polar bear image *carbon emissions/ energy issues*: image of lightbulbs *people/ talking heads*: images of situated climate politics
Smith & Joffe, 2009	UK; 1 January 2000 – 31 December 2006; three Sunday broadsheet newspapers (Sunday Times, Sunday Telegraph and Observer), three Sunday tabloid newspapers (News of the World, Mail on Sunday and Sunday Mirror); n= 300 articles; search terms: 'global warming' OR 'climate change' OR 'greenhouse effect'	Content analysis and thematic analysis	*climate change impacts*: depiction of climate change as an issue affecting domestic populations; trying to show climate change as a current threat (instead of long-term) *people/ talking heads*: images of an affected public, political leaders, Celebrity icons *Graphs and models*: graphical representations
Walsh, 2010	Worldwide; 2007; 4th IPCC assessment report	Examination of visualizations of climate models in the SPM	*Graphs and models*: graphs as most dramatic rhetorical devices

Note. IPCC = Intergovernmental Panel on Climate Change; SPM = summary for policy makers.

in different cultural contexts (Lester & Cottle, 2009). In Swedish newspapers and on television, visual representations of climate change are often threatening as well, showing floods and human suffering from heat waves (Hoijer, 2010). Impactful imagery is one of the three main themes in the British press (Smith & Joffe, 2009) and among the five most common themes in climate change coverage in Swiss, Austrian, and German newspapers (Rüegg, 2015; see also Grittmann, 2013, 2014). Vulnerability and danger also appear as common themes in imagery for climate change action campaigns (Manzo, 2010b). Doyle (2007) shows that Greenpeace uses pictures to emphasize the impacts of climate change.

- *Nature themes*: Nature is another major theme in climate change imagery, particularly pristine wilderness, flora, and fauna (Rebich-Hespanha et al., 2015). Manzo (2010a) identifies the polar bear as a particular icon of climate change, used in many commercial and political campaigns. For example, Greenpeace strategically used the image of the polar bear in Canada to represent climate change (Slocum, 2004). Legacy media, for example, in the U.S. news media, have used polar bears and vulnerable landscapes as prevalent visual representations of climate change (Rebich-Hespanha et al., 2015).
- *People/"talking heads"*: Personifications of climate change in the form of "talking heads" is among the most common climate change visualizations in the U.S., British, and Australian press (O'Neill et al., 2013; cf. Smith & Joffe, 2009). This personification is particularly true for politicians (Rebich-Hespanha et al., 2015), especially during events such as the United Nations Climate Change Conferences (COPs). Eide (2012) analyzes visual imagery of the Copenhagen climate summit in 2009, finding that most images focused on people—not only on political leaders but also on victims of climate change and protesters. Another study of Canada's main national newspapers' coverage of climate change in 2008 notes the dominance of human imagery (DiFrancesco & Young, 2011). With regard to the German-speaking regions studied in this article, a content analysis of print and online coverage finds that images of people, particularly politicians, are the media's most prominent visualizations in all three countries (Rüegg, 2015).
- *Graphs and models*: Other studies analyze the graphic visualization of climate change data (models). Schneider (2009, 2012) shows that the hockeystick graph and the blue planet turning red are distinctive ways of visualizing climate change. Representations of climate change via graphs and tables are prominent in the British press (Smith & Joffe,

2009). Similarly, Walsh (2010) points out the significance of computer simulations of climate models for climate change imagery, and German and Swiss newspapers use infographics in their climate change coverage (Rüegg, 2015).

- *Carbon emissions/energy issues*: A less dominant but important theme involves images related to carbon emissions (e.g., coal power plants) depicting the causes of climate change (Grittmann, 2013, 2014). Visualizations of energy efficiency, alternative energies, and energy prices also serve as visual frames in climate change communication in the United States (Rebich-Hespanha et al., 2015) and in campaign communications (Doyle, 2007).

In sum, these studies show that visual representations of climate change focus on people and nature being threatened by the *impacts of climate change* (cf. O'Neill & Nicholson-Cole, 2009). This focus is reflected in the other dominant visual themes of *people* and *nature*. *Graphs* and *models* are often used as well as images of *carbon emissions* and *energy issues*.

The literature also suggests that the *use of imagery in climate change coverage is similar across different countries*—from Anglo-American countries (United States, United Kingdom, Australia, Canada) to European (Sweden, Germany, Austria, Switzerland), African (South Africa), and Asian countries (Singapore, India)—as well as across different media such as newspapers or television. The media seem to create a mostly homogenous visual discourse of climate change as a transnational issue. This homogeneity is understandable when considering that media coverage on climate change in most countries is driven by the same international events (Schäfer, Ivanova, & Schmidt, 2014), that media organizations in different countries are often owned by the same corporations (e.g., Rupert Murdoch in the United Kingdom and United States, Bertelsmann AG in Europe), and that journalists often use the same agencies and databases to retrieve images for their coverage, particularly for climate change (Grittmann, 2012). As the slow and complex process of climate change is difficult to depict, journalists often rely on visual icons offered by international agencies like Getty Images (Hansen & Machin, 2008).

Perceptions of Climate Change Imagery

Compared to studies analyzing media visualizations of climate change, far fewer studies have scrutinized how audiences perceive these visualizations. Drawing on theories of media effects, research in the field of visual communication, particularly research on visual framing effects, has shown that images and the way they present specific content can influence individual perceptions of an issue (Geise & Baden, 2015; Gibson & Zillmann, 2000; Powell, Boomgaarden, de Swert, & de Vreese, 2015). It is notable, however, that such perceptions are socially and culturally embedded, that sociocultural contexts influence how audiences perceive media presentations, and that this may lead to differences in the perceptions of similar media representations (see the seminal study of Liebes & Katz, 1993; see also Clausen, 2004). Therefore, we study whether images of climate change, which are similar across different sociocultural contexts, are perceived similarly in these differing contexts.

Research on the perceptions of climate change imagery has established that, generally, visual themes dominating media coverage also resonate in people's perceptions. In one of the first analyses, Nicholson-Cole (2005) focused on how U.K. citizens conceptualize climate change visually, demonstrating that individuals found that the easiest way to conceptualize the abstract issue of climate change was to visualize present and future impacts and the relationship to their personal lives (Nicholson-Cole, 2005). Similarly, Leiserowitz (2006) used a national U.S. survey to reconstruct the affective images people associate with climate change, with the most frequently mentioned images being melting ice and heat (Leiserowitz, 2006).

O'Neill and Hulme (2009) and O'Neill and Nicholson-Cole (2009) studied climate change images with respect to public engagement in the United Kingdom. They demonstrated that people were most drawn to personally relatable icons, such as depictions from their local environment (O'Neill & Hulme, 2009), while dramatic and frightening images were disengaging, making them feel unable to act (O'Neill & Nicholson-Cole, 2009).

In the most comprehensive study so far, O'Neill et al. (2013) analyzed the perceptions of climate change imagery in the United States, the United Kingdom, and Australia. They asked people to sort 40 climate change images with respect to whether the image made them "feel that climate change is important" (p. 415) and whether it made them feel that they "can do something about climate change" (p. 416). The selected pictures were regarded as a relevant set of statements reflecting the larger concourse of visual communication of climate change. O'Neill et al. found *shared perceptions of climate change imagery by people in the United Kingdom, United States, and Australia*. Again, the visual themes prominent in the media were reflected in participants' perceptions: Images of climate change impacts were associated with "the sense of importance of the issue of climate change (saliency)" (p. 420), whereas "energy futures imagery promote[d] self-efficacy" (p. 419). At the same time, images of politicians and celebrities ("talking heads") were not related to self-efficacy or salience perceptions; they could even undermine feelings of self-efficacy. Climate change graphs were not associated with salience or self-efficacy. All of these results were very consistent in the three countries.

These studies suggest that climate change imagery is associated with salience and efficacy perceptions, and that these perceptions are similar across countries. There are only few such studies yet, and they focus almost exclusively on Anglophone Western countries, namely, the United States, the United Kingdom, and Australia (see also Schäfer & Schlichting, 2014). Visual framing research, however, has not yet provided a broader empirical basis on to what extent perceptions of visual representations are similar in different cultural contexts. Therefore, we replicate O'Neill et al.'s (2013) study in a European context and investigate public perceptions of climate change imagery in Germany, Switzerland, and Austria. These countries are excellent cases to study whether perceptions of visual representations differ cross-culturally—not only because climate change imagery has rarely been studied in continental European countries but also because these countries differ from the Anglophone world in crucial dimensions. The elaboration and interpretation of images depend on individuals' existing knowledge about and attitudes toward the issue presented (Geise & Baden, 2015), and such differences can be found between Anglophone and the three German-speaking countries: Attitudes toward climate change in Germany, Switzerland, and Austria differ compared not only to the United States but also to the United Kingdom and Australia (Metag, Füchslin, & Schäfer, 2015). The level of climate change skepticism in Europe is lower (Engels et al., 2013; European Commission, 2009), the existence of climate change has been accepted more widely, and a relatively broad consensus exists that political measures to fight it are necessary (Peters & Heinrichs, 2008; Schäfer, forthcoming; Weingart, Engels, & Pansegrau, 2000). Moreover, climate change affects countries like Australia more (e.g., through strong heat waves and floods) than European countries (DARA and the Climate Vulnerable Forum, 2012). Images of certain climate change impacts thus might evoke less feelings of climate change being a salient, important issue in regions where such impacts are less likely to manifest themselves. General environmental concern is higher in Germany, Switzerland, and Austria than in the United States and Great Britain (Franzen & Vogl, 2013). In addition, the individual responsibility of citizens to care for the environment is more established in these countries (Hadler & Haller, 2011), which might result in different perceptions of climate change imagery, in particular with regard to self-efficacy.

In light of these differences between German-speaking and Anglophone countries, the question arises as to whether perceptions of climate change imagery are similar or different. We will scrutinize this question, focusing on two crucial dimensions of image perceptions: perceptions of salience and self-efficacy. Both of these are important as media research on climate change has often investigated the link between media coverage and public engagement with climate change (e.g., Whitmarsh, O'Neill, & Lorenzoni, 2011), and public engagement can be achieved if the public perceives climate change as an important issue, that is, as salient, and if people also feel enabled to do something about it (self-efficacy; O'Neill & Nicholson-Cole, 2009). Since salience and self-efficacy are relevant preconditions of public engagement, we study whether the conventional perceptions of climate change images with regard to salience and self-efficacy also hold in German-speaking regions or if other, unanticipated perceptions of which images promote salience and which images promote self-efficacy emerge. Thus, the study contributes to theoretical and empirical research of cross-cultural perceptions of images by posing the following research question:

> **Research Question:** How do people interpret climate change imagery in Germany, Switzerland, and Austria?

We follow O'Neill et al.'s (2013) approach and use the Q method to analyze which images people perceive as conveying the importance of climate change (salience) and which images convey a sense that they can do something about climate change (self-efficacy). We then compare the perceptions of climate change imagery in our German-speaking sample to the shared perceptions found in Anglo-American countries by O'Neill et al. (2013).

Methodology

As perceptions of images are individually constructed and often difficult to verbalize, a subjective approach to studying them must be taken (Nicholson-Cole, 2005). Therefore, the aforementioned studies often used qualitative methods, such as focus groups or semistructured interviews (Nicholson-Cole, 2005; O'Neill & Hulme, 2009). This study uses Q sorting, a methodology that is particularly helpful in the study of subjective perceptions and hidden meanings (McKeown & Thomas, 2013; Stephenson, 1953). Without depending on verbalization, Q methodology allows researchers to grasp associations that participants generate from images (Lobinger & Brantner, 2015).

Q methodology combines qualitative and quantitative procedures (Davis & Michelle, 2011). First, participants sort a number of predefined statements (in this case, images relating climate change) on a quasi-normal distribution grid (see Figure 1). Then, a statistical Q factor analysis, which is a factoring technique grouping participants instead of variables, is used to analyze the different sorts (McKeown & Thomas, 2013). By sorting different statements

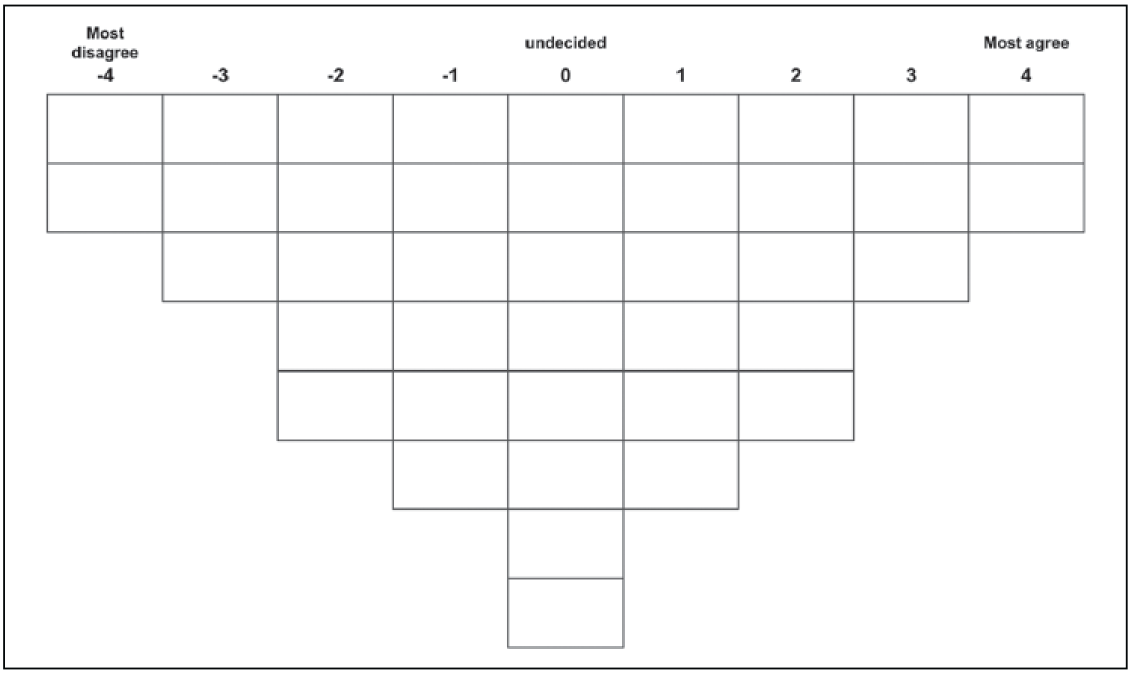


Figure 1. Q sorting grid.

or images, the method makes it possible to transfer qualitative evaluations to a quantifiable scale (Geise & Kamps, 2012).

The method has been applied in research on political attitudes and opinions, market research, environmental psychology, and gender research (Müller & Kals, 2004). It has also been used in media and audience studies (see Davis & Michelle, 2011, pp. 551f.; Lobinger & Brantner, 2015; Singer, 1997), including assessments of audience responses to images (e.g., Geise & Kamps, 2012; Lobinger & Brantner, 2015; O'Neill et al., 2013; O'Neill & Nicholson-Cole, 2009), some in the context of climate change (Hobson & Niemeyer, 2013; O'Neill et al., 2013).

In our study, participants sorted images related to climate change with respect to different variables. We supplemented the sorting procedure with a standardized questionnaire before and with open-ended interviews after the Q sorting session, allowing participants to expand on their sorting decisions.

Materials

The first step of a Q study is to develop a comprehensive array of relevant communicative content (McKeown & Thomas, 2013; Orchard, Fullwood, Morris, & Galbraith, 2014). In our case, we put together a set of images related to climate change. Ideally, a Q sample constitutes a "comprehensive but manageable representation of the concourse from which it is taken"

(McKeown & Thomas, 2013, p. 23). In more structured samples, themes should be represented proportionally or according to external criteria, such as prevalence in real life. As we replicated the study by O'Neill et al. (2013), we got access to the images used in their study and followed their sample structure, which was based on a comprehensive media content analysis in the three most frequently researched countries—the United States, United Kingdom, and Australia. Given the strong parallels between climate change imagery in different countries revealed in the literature review, this structure should not compromise our sample for the Q sorts.

In addition, we checked whether O'Neill et al.'s (2013) set of images represented the pictures used in German-speaking media by drawing on the small number of existing studies on climate change imagery in the German-speaking world (Grittmann, 2013, 2014; Pleger, 2013; Rüegg, 2015). We also considered the currently unpublished findings of a large research project that coded German newspaper images of climate summit coverage from 2010 to 2013 (Wessler, Lück, & Wozniak, 2014; Wozniak, Lück, & Wessler, 2015). This step verified that the selection of images was largely appropriate, albeit some images had to be adjusted to the different national contexts, for example, by replacing the pictures of political leaders with comparable domestic ones, by replacing the image of the flooding map of an English river with a German one (River Elbe), or by substituting English with German words.

The final set included 40 images related to climate change (see Table 2).[1] It represents the visual discourse on climate change in the given countries and adheres to country-specific information. Images representing the theme of *impacts and threats of climate change* include the following: landslide, ski slopes with little snow, Inuit, car in snowstorm, low reservoir, cracked/dry earth, fighting bushfires, aerial views of floods, coral atolls, coastal erosion, and a person in the desert. Images conveying *nature themes* include coral reefs, icebergs, polar bear, glacier, the earth from space, volcano, and felling tropical forests. Doris Leuthardt/Angela Merkel/Werner Fayman, climate scientist, Al Gore, Bono, and Barack Obama represented pictures of *people/talking heads*. The temperature graph and flooding map (River Elbe) were climate change *graphs and models*. Images relating to the *carbon emissions/energy issues* theme included the electric car, meat counters/red meat for sale, protests in front of a coal power plant, tractor on a farm, home insulation, solar panels, wind farms, ecohouse, nuclear power plant, planes at airport, smokestacks, traffic jam, and fuel pump.

Participants

As Q methodology aims to uncover different viewpoints and does not strive for generalizability, sample size is not that important; some Q studies are

Table 2. Images Used in the Study.

1.	Electric car	2.	Meat counter/red meat for sale	3.	Doris Leuthardt/ Angela Merkel/ Werner Faymann	4.	Protest in front of a coal power plant
5.	Temperature graph	6.	Flooding map (River Elbe)	7.	Ski slopes with little snow	8.	Inuit
9.	Landslides	10.	Coral reef	11.	Icebergs	12.	Polar bear
13.	Glacier	14.	Car in snowstorm	15.	Tractor on farm	16.	Low reservoir
17.	Cracked/dry ground	18.	Deckchairs	19.	Fighting bushfires	20.	Flood aerial view
21.	Coral atoll	22.	Coastal erosion	23.	Globe from space	24.	Climate scientist
25.	Home insulation	26.	Church congregation	27.	Solar panels	28.	Wind farms
29.	Ecohouse	30.	Nuclear power plant	31.	Planes at airport	32.	Smokestacks
33.	Traffic jam	34.	Volcano (eruption)	35.	Felling tropical forest	36.	Fuel pump
37.	Al Gore	38.	Person in the desert	39.	Bono	40.	Barack Obama

even conducted on a single-case (n = 1) basis (McKeown & Thomas, 2013). In our study, however, 75 respondents from three comparable cities participated in the study: 25 in Hamburg (Germany), 25 in Zurich (Switzerland), and 25 in Vienna (Austria). A research design with 75 participants and 40 images is in line with Q study conventions. Participants were recruited in systematically selected, socioeconomically different neighborhoods (the selection was similar in all three cities). To recruit, we used supermarket postings and online platforms, and we approached people on the street. Each participant received a financial incentive for participation.

We aimed to include participants with different backgrounds by recruiting different age groups, sexes, and educational backgrounds. In total, 38 participants were female and 37 male; 28 were 18 to 29 years old, 25 were 30 to 49 years old, and 22 were over 49 years old. Of these, 21 had an academic degree, 28 a high school degree, and 26 a lower school degree. The questionnaire administered before each sorting session ensured that participants also varied in their views on climate change ("To what extent would you say you are interested in climate change?" 1 = *not at all*, 4 = *very much; M* = 3.08, *SD* = 0.67; "How concerned are you about climate change?" 1 = *not at all concerned*, 4 = *very concerned; M* = 3.08, *SD* = 0.77).

Procedure

Sorting sessions took place in Hamburg, Zurich, and Vienna in February 2014. Guided by a research assistant, each session took about 45 minutes. Participants were first asked to fill in the paper-and-pencil questionnaire and to read the sorting instructions.[2] The 40 images were printed on sorting cards and distributed to the participants stacked randomly. The sorting grid comprised a continuum from −4 (*most disagree*) to +4 (*most agree*). The distribution of images was forced, allowing more images to be placed in the middle categories than in the outer, extreme categories. For example, only two pictures could be ranked in the "most disagree" and two pictures in the "most agree" categories.

Participants undertook two Q sorts. First, they sorted the images based on the statement "This image makes me feel that climate change is important." The second sorting was based on the statement "This image makes me feel I can do something about climate change." The pictures were removed from the grid and mixed again between sorts. Participants were instructed to sort intuitively; there was no "right" sorting, and their subjective views were our main interest. After each sort, participants were interviewed about their sorting. In the interviews, particular attention was paid to pictures at the extremes of the distribution and to images about which participants felt strongly. The interviews were recorded, and photos of the sorts were taken as backup.

Analysis

The analysis of Q sorts relies on an inverted factor analysis (Q factoring), grouping participants instead of statements (McKeown & Thomas, 2013). Q sorts were analyzed using Advance Q 2.08 (Niemeyer, 2013), a program that calculates intercorrelations between Q sorts to group similar participants and allow for different adjustments during the analysis.[3] A principal component analysis was conducted with varimax rotation. The approach included all 75 participants together as we aimed to uncover shared perceptions of climate change imagery among the participants.

We conducted the analysis stepwise and aimed for a factor solution that accounted for the greatest number of uniquely defined responses by the smallest number of factors (Michelle, Davis, & Vladica, 2012), excluding "confounded" and statistically insignificant sorts (Michelle et al., 2012, p. 124). First, only factors with an eigenvalue over 1 were considered, and the level of confidence was .99. We proceeded with the analysis by reducing the maximum number of factors each time until achieving the final factor solution. This final factor solution was achieved when the number of factors still accounted for as much variance as possible but the factors were still distinct and highly interpretable. Compared to O'Neill et al. (2013), we not only interpreted the first factor that emerged and explained the largest part of variance representing the mainstream view (O'Neill et al., 2013, p. 416) but also considered the other emerging factors. The Q method is especially useful for observing perspectives deviating from the mainstream view.[4]

Results

Salience

The first analytical dimension focuses on the extent to which different images promote the perception that climate change is an important issue. For this dimension, the analysis produced a strong first factor explaining most of the variance and a comparatively weak second factor. Table 3 displays the results for the salience sorts for all 75 participants. Factor scores are reported with the z scores for each factor converted back into an array of typical responses using the same range of responses presented to the participants (i.e., −4 to +4). For clarity, only the images ranked on the +4, +3, −3, and −4 positions for each factor are displayed in Tables 3 and 4.

Climate Change Impacts

The *climate change impacts* factor explains most of the variance and includes often-used visual representations in the media, such as floods, people in the desert, landslides, polar bears, and drought. The pictures show objects affected by climate change or the impacts themselves. Flooding is often perceived as a strong and imminent threat, perhaps due to the 2013 floods of the River Danube in Austria and Germany ("This is what affects us ourselves, in Germany, these floods"; P27, f, >49, acad., GER).[5] Flooding is also strongly related to climate change ("With the flooding, for example, it is clear: Climate change!"; P29, m, 30-49, low, GER). Flooding is a strong image that appears often on television (Lester & Cottle, 2009), and the polar bear is one of the most typical pictures associated with global warming (cf. Manzo 2010a): "The polar is simply *the* image of climate change. You always think first of the polar bear which does not have any ice to walk on anymore" (P11, f, 18-29, high, CH). Pictures associated with drought and other climate change impacts (landslides) are salient because they depict threats to humans: "These pictures just evoked the strongest reaction because there is a person in them who is affected by a drought" (P9, m, >49, acad., CH) or "This is what can

Table 3. Results for Salience Sorts.

Factor 1. Climate change impacts (35.63%): "With the flooding it is clear to me: Climate change!" (P29, m, 30-49, low, GER)		
+4	Stmt20	Flood aerial view
+4	Stmt38	Person in the desert
+3	Stmt9	Landslide
+3	Stmt17	Cracked/dry ground
+3	Stmt12	Polar bear
−3	Stmt3	D. Leuthardt/A. Merkel/W. Faymann
−3	Stmt25	Home insulation
−3	Stmt29	Ecohouse
−4	Stmt26	Church congregation
−4	Stmt18	Deckchairs
Factor 2. Causes (6.97%): "I think that climate change mostly has to do with trees dying and polluted air." (P33, f, 30-49, high, GER)		
+4	Stmt32	Smokestacks
+4	Stmt35	Felling tropical forest
+3	Stmt33	Traffic jam
+3	Stmt4	Protest in front of coal power plant
+3	Stmt20	Flood aerial view
−3	Stmt14	Car in snowstorm
−3	Stmt25	Home insulation
−3	Stmt34	Volcano
−4	Stmt26	Church congregation
−4	Stmt18	Deckchairs

Note. Factor scores are converted from z scores. Percentages are the explained variance for each factor. "Stmt" indicates the picture number.

evoke danger. Like a catastrophe which might happen. It is also something that can make you scared" (P23, m, 30-49, acad., CH). Participants also made clear that they recognized the images from the mass media. Participant 53 (m, 18-29, acad., AUS) summarizes, "Pictures which remind me most of climate change. These are exactly those pictures which I relate to climate change and which are used in media." In contrast, the church congregation, deckchairs in the sun, and pictures of political leaders do not seem to convey the importance of climate change as an issue. As a German participant pointed out, "The church just does not have anything to do with climate change in my view" (P27, f, >49, acad., GER).

Respondents do not seem to trust that politicians will do something to fight climate change. An Austrian participant made this point clear when

Table 4. Results for Self-Efficacy Sorts.

Factor 1. Renewable energies (37.19%): "These are things which you need to be responsible for yourself. That you pay attention to how much energy you are using. That you rely on solar and wind energy more." (P19, f, 18-29, high, CH)		
+4	Stmt27	Solar panels
+4	Stmt28	Wind farm
+3	Stmt1	Electric car
+3	Stmt2	Meat counter/meat for sale
+3	Stmt33	Traffic jam
−3	Stmt5	Temperature graph
−3	Stmt9	Landslide
−3	Stmt12	Polar bear
−4	Stmt11	Iceberg
−4	Stmt20	Flood aerial view
Factor 2. Mobility (8.42%): "This shows me that I should use the car less." (P15, m, 18-29, acad., CH)		
+4	Stmt1	Electric car
+4	Stmt33	Traffic jam
+3	Stmt36	Fuel pump
+3	Stmt31	Planes at airport
+3	Stmt27	Solar panels
−3	Stmt26	Church congregation
−3	Stmt40	Obama
−3	Stmt37	Al Gore
−4	Stmt34	Volcano
−4	Stmt39	Bono

Note. Factor scores are converted from z scores. Percentages are the explained variance for each factor. "Stmt" indicates the picture number.

explaining why he ranked the picture of Werner Faymann, the Austrian chancellor, as the least salient: "Politicians come off worst in this respect. Because their statements are just not trustworthy" (P62, m, >49, low, AUS). The images of the ecohouse and home insulation do not seem to be related to perceptions of salience as some participants did not recognize how the pictures related to climate change (ecohouse: "[. . .] this is a nice house. But I cannot identify whether it is built in a climate-friendly way" [P35, f, 18-29, low, GER]). As for home insulation, one participant stated, "I had to think hard about what this actually shows until one gets that the guy is insulating his roof. First I thought, there are bales of straw or something like that on the picture" (P36, m, 30-49, high, GER).

Causes of Climate Change

The second factor includes *causes* for environmental problems with images of smokestacks, deforestation, protests in front of a coal power station, and traffic jams. A respondent pointed out that these images are "negative images not only of the consequences but of the causes, related to the cars [. . .] and the emissions. They have a strong impact on me" (P12, f, 30-49, low, CH). Respondents noted that there might be a connection between the causes, such as carbon emissions and consequences: "I think that climate change mostly has to do with trees dying and that there is polluted air. And these are the most important aspects of global warming in my view" (P33, f, 30-49, high, GER). As the images of smokestacks and traffic jam reveal, carbon emissions are perceived as an environmental problem and as a cause for climate change. Participant 62 illustrates this position well: "The carbon emissions, air pollution, industrial areas, factories—this was very dominant in my view" (m, >49, low, AUS). Pictures of protests in front of a coal power station and traffic jams illustrate humanity's immense energy needs and the related carbon emissions, while pictures of deforestation illustrate how the problem of carbon emissions is continuously intensified by commercial interests.

Similar to the first factor, the church congregation, deckchairs, and home insulation are perceived as least conveying the importance of climate change. Regarding the image of the volcano and the car in the snow, many participants did not relate a volcanic eruption or snowfall to climate change: "I couldn't make sense of the volcano with respect to climate change. I didn't see a connection there; whether volcanoes are erupting more often now due to global warming" (P26, m, 18-29, acad., GER). Snowfall was not perceived as having anything to do with climate change: "Snow does not really stand for climate change; snow has existed forever" (P43, f, 30-49, low, GER).

In sum, images of climate change impacts as well as causes of global warming are related to perceptions of salience. Among this imagery, visual representations of who is affected and threatened by global warming play an important role (animals, biodiversity, and humankind). Flooding or a person in the desert raise awareness in people that climate change is an important issue because they feel that someone or something will be negatively affected.

Self-Efficacy

The second analytical dimension focused on the extent to which different images promote the perception that audience members themselves could do something about climate change. Table 4 displays the results for this self-efficacy dimension. Again, we find one strong first factor and a second, weaker factor.

Renewable Energies

This factor depicts solutions to mitigate climate change using *clean energies*, thereby replacing fossil fuels and protecting the climate. The wind park, solar panels, and electric car represent renewables, while the traffic jam illustrates the need for alternative energies. It seems clear to participants that people can do something about climate change if they use these renewable energies: “These are things which you need to be responsible for yourself. [. . .] That you pay attention to how much energy you are using. That you rely on solar and wind energy more” (P19, f, 18-29, high, CH).

Images showing individual or consumer opportunities to reduce carbon emissions also promote self-efficacy. By abstaining from eating meat, for example, people can fight global warming: “This is exactly where I have the easiest choice. If I want less carbon emission I have to think about: Do I want to eat a lot of meat, do I want to pay attention to where the meat comes from or not? (P27, f, >49, acad., GER)”.

Individual responsibility is reflected in images demonstrating a choice to participants in terms of what they can abstain from or change in their daily lives: “Do I buy certain products, am I driving a car, what does my consumption look like, these are things that I can actually personally influence” (P35, f, 18-29, low, GER). As another participant put it, “I use my car less. This affects me because with my behavior I can contribute to not producing so many emissions [. . .]” (P57, m, 30-49, acad., AUS).

In many cases, images ranking low in self-efficacy depict climate change impacts or natural disasters. The landslide, flooding, and iceberg images undermine feelings of self-efficacy. Also, the image of the polar bear does not seem to convey to the respondents that they can do something about climate change: “Yes, this is something where I think: This shows the impacts of climate change but you can’t do anything about it” (P53, m, 18-28, acad., AUS). In addition, imagery that relates to scientific research and statistics, such as temperature graphs, does not seem to be associated with self-efficacy.

Mobility

The *mobility* factor tackles the problem of traffic and the daily need for gasoline and energy, as exemplified by images of the electric car, traffic jams, fuel pump, and planes at the airport. Respondents perceive the electric car as a means of self-efficacy and a potential solution to the problem of enhanced mobility in modern societies: "I drive a car myself and I think one can consider to stop using conventional petrol and how I could use a car with alternative energies" (P47, m, 18-29, acad., GER).

The factor includes holiday travel as well as routine mobility. Holiday travels relate to further and longer journeys, while routine mobility refers to everyday mobility. The planes at the airport convey that in terms of vacations or longer journeys, people can do something about climate change: "I thought about what I can do myself. What affects myself. And holidays and using the plane, I can affect that myself" (P23, m, 30-49, acad., CH). Relating more to everyday actions, routine mobility is depicted by images of traffic, cars needing gas, and various forms of mobility, such as the electric car. One respondent said this about the traffic jam image: "This shows me that I should use the car less" (P15, m, 18-29, acad., CH). Solar panels also play a role in the mobility factor by presenting solutions to the energy crisis: "I would support alternative energies such as the windmill or solar power or green electricity" (P59, f, 30-49, high, AUS).

In this factor, the volcano eruption is a natural disaster that related least to feelings of self-efficacy. Identifiable "talking heads," such as political leaders, were often ranked as less efficacious, for example, Barack Obama, Al Gore, or U2's Bono. The church congregation also was not perceived as promoting the idea that people can do something about climate change. The connection between the church and climate change was unclear to many participants: "I put the image of the church there because I do not have a personal relation to it, and the picture doesn't give me the feeling that I should do something" (P31, f, 18-29, high, GER).

Overall, perceptions of self-efficacy are reflected in images of renewable energies, carbon emissions, mobility, and traveling in the context of climate change. This kind of imagery relates to people's lifestyles and their personal choices in everyday life.

Discussion and Conclusion

Imagery is an important and widely used facet of media reporting on climate change, and certain visual representations seem to be associated with particular audience perceptions (O'Neill et al., 2013). To date, however, studies have mostly analyzed the Anglo-American world (Schäfer & Schlichting, 2014). Going beyond this limitation, our study contributes to visual communication research by analyzing whether these perceptions are cross-culturally similar. It analyzed perceptions of climate change imagery in the major German-speaking countries: Germany, Switzerland, and Austria. Based on Q sorting methodology, we found that certain images are related to respondents' feeling that climate change is important (salience), and that other images are associated with respondents' perceptions that they can do something about climate change (self-efficacy).

First, visual representations of climate change impacts are perceived as conveying the importance of global warming, and these images are very often used in the Anglophone (e.g., O'Neill et al., 2013) and German-language media (Rüegg, 2015). Aerial views of floods and the desert seem to be particularly impressive, attracting people's attention and creating fear.

At the same time, images of climate change impacts may undermine perceptions of self-efficacy. They make climate change appear as an overwhelming, forceful natural development, and participants think that they, as individuals, are helpless and cannot do anything to stop it.

The set of images associated with self-efficacy is notably distinct from images related to salience, and it contains pictures that are used less often in the media. It includes images of clean and renewable energies, forms of mobility, and lifestyle and consumption choices; in essence, the images depict ways to reduce carbon emissions.

Imageries of identifiable people and politicians are not related to perceptions of salience or self-efficacy. Politicians are not perceived as conveying the idea that climate change is an important issue, nor do they convey that individuals can do anything about climate change.

These results need to be further substantiated and refined, for example, by distinguishing different subgroups based on gender, age, education, or attitudes about climate change or by extending the analysis to respondents from rural areas. Nonetheless, a number of conclusions can already be drawn. One the one hand, we find some, albeit small, differences between our results and those of O'Neill et al.'s (2013) for Australia, the United States, and the United Kingdom. Comparing the two studies, the picture of the coral reef that ranked high for salience in O'Neill et al.'s (2013) study does not appear to be associated with salience perceptions in our study—maybe because of the greater distance between German-speaking countries and coral reefs. By contrast, felling forests is more strongly related to climate change being an important issue than it seemed to be for respondents in the United States, the United Kingdom, and Australia. Pictures of home insulation or protest in front of a coal power plant relate differently to self-efficacy. They were important in O'Neill et al.'s study, but they do not play much of a role for feelings of self-efficacy in our study. Some respondents did not associate the home insulation image with energy efficiency.

This indicates that perceptions of climate change imagery are domesticized to some extent. Overall, however, our results are remarkably similar to

O'Neill et al. (2013). Although people in the analyzed German-speaking countries differ in their attitudes toward climate change from people in the United States, the United Kingdom, or Australia, their perceptions of climate change imagery seem to be rather comparable. This suggests that climate change imagery, and potentially imagery of other transnational issues as well, is perceived in similar ways cross-culturally, transcending geographical and linguistic boundaries.

These results are in line with the broader research into the visual communication of climate change. That images of strong climate change impacts such as floods are not linked to perceptions of self-efficacy, for example, mirrors the finding that fear-inducing pictures were ineffective in evoking Britons' engagement with climate change (O'Neill & Nicholson-Cole, 2009). Also similar to Germany, Switzerland, and Austria, images of identifiable people, particularly politicians, were not related to perceptions of salience and barely related to self-efficacy perceptions in the United States, United Kingdom, and Australia (O'Neill et al., 2013). Pictures of politicians being only slightly related to perceptions of salience or self-efficacy is an interesting finding because such images are among the most common in the media (Eide, 2012; O'Neill, 2013; Smith & Joffe, 2009). It seems that the most common pictures used in the media either entirely fail to evoke the feeling that climate change is important or fail to make people believe they can do something about it, which is the case for "talking heads." Alternatively, they are associated only with high salience perceptions but not with perceptions of self-efficacy—as is the case for impact imagery. Imagery highlighting self-efficacy appears less often in the media.

Normatively, these findings raise interesting points. The imagery predominantly used by the media does not seem to be suitable to raise perceptions of salience and self-efficacy. Even if some of the frequently used pictures—like those of climate change impacts—are associated with climate change being an important issue, images conveying the feeling of self-efficacy are barely used in the media. While mass media imagery of climate change is able to draw attention to the issue, it does not provide options for action, at least not through visual communication. While this is understandable given the media's attempts to maximize audience appeal and attract their attention, one may raise the question of the normative function of media coverage. If one advocates the position that journalists are supposed to engage people in taking action against climate change—which would be in line with recent demand for more "constructive news" (Haagerup, 2015)—then current climate change imagery is ill-suited. However, one could argue that by using images that run against common public perceptions of climate change, journalists can challenge these mainstream perceptions. Offering new perspectives can also be regarded as journalists' responsibility. In contrast to journalists, climate change campaigners aim to raise awareness of the issue, and thus our results can be used to assess whether their campaigns use the most effective images to raise awareness about global warming.

The results may also be valuable in reflecting upon the imagery used in science communication; for example, they might bring into question the effectiveness of the graphs and models used when covering the Intergovernmental Panel on Climate Change report or other scientific studies on climate change (Mahony & Hulme, 2014; Schneider, 2012). Given the fact that most people—at least in German-speaking countries—no longer question the problem of climate change itself, a change in the climate change imagery employed by the media and other communicators might contribute to motivating people to become more active in containing it.

In any case, this research demonstrates that it may be useful for future studies to differentiate between different dimensions of perceptions, such as salience and self-efficacy. It would also be fruitful to study the perceptions of media producers like journalists and photographers and compare them with audience perceptions. Since salience and self-efficacy are crucial for public engagement, a further step could be to quantitatively assess, for example, in an experimental design, whether perceptions evoked by these images have an effect on other relevant dimensions for engagement with climate change, such as participation in climate action campaigns.

Acknowledgments

The authors would like to thank Saffron O'Neill for granting access to the images and materials used in their study and Simon Niemeyer for providing his Q software and advice on its use. We would also like to thank the anonymous reviewers for their helpful comments on the manuscript.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Data collection was partly funded by the German Research Council DFG through the Cluster of Excellence "Integrated Climate System Analysis and Prediction (CliSAP)'', EXC 177, University of Hamburg.

Notes

1. Readers interested in further details should contact the first author.
2. The questionnaire requested participants to spontaneously note three affective images of global warming and respond to attitudinal statements about climate change.
3. The software was developed by Simon Niemeyer and is provided by him on request. It is designed to analyze Q sort data and allows the selection of different factor rotations and thresholds.
4. A preliminary analysis of those respondents who yield factor loadings of 0.4 or higher for each factor revealed no significant differences with respect to the respondents' nationality.
5. Abbreviations for the participants are as follows: P = Participant Id; f = female, m = male; >49 = older than 49 years, 30-49 = between 30 and 49 years old, 18-29 = between 18 and 29 years old; acad. = academic degree (university level), high = high school degree, low = lower degree; GER = Germany, AUS = Austria, CH = Switzerland.

References

Clausen, L. (2004). Localizing the global: "Domestication" processes in international news production. *Media Culture & Society*, *26*, 25-44.

DARA and the Climate Vulnerable Forum. (2012). *Climate vulnerability monitor: A guide to the cold calculus of a hot planet* (2nd ed.). Madrid, Spain: Author.

Davis, C. H., & Michelle, C. (2011). Q methodology in audience research: Bridging the qualitative/ quantitative "divide"? *Participations*, *8*, 527-561.

DiFrancesco, A. D., & Young, N. (2011). Seeing climate change: The visual construction of global warming in Canadian national print media. *Cultural Geographies*, *18*, 517-536. doi:10.1177/1474474010382072

Doyle, J. (2007). Picturing the clima(c)tic: Greenpeace and the representational politics of climate change communication. *Science as Culture*, *16*, 129-150. doi:10.1080/09505430701368938

Eide, E. (2012). Visualizing a global crisis. Constructing climate, future and present. *Conflict & Communication Online*, *11*(2), 1-16.

Engels, A., Hüther, O., Schäfer, M., & Held, H. (2013). Public climate-change skepticism, energy preferences and political participation. *Global Environmental Change*, *23*, 1018-1027. doi:10.1016/j.gloenvcha.2013.05.008

European Commission. (2009). *Special Eurobarometer 322: European attitudes towards climate change*. Retrieved from http://ec.europa.eu/public_opinion/archives/ebs/ebs_322_en.pdf

Franzen, A., & Vogl, D. (2013). Two decades of measuring environmental attitudes: A comparative analysis of 33 countries. *Global Environmental Change*, *23*, 1001-1008. doi:10.1016/j.gloenvcha.2013.03.009

Geise, S., & Baden, C. (2015). Putting the image back into the frame: Modeling the linkage between visual communication and frame-processing theory. *Communication Theory*, *25*, 46-69. doi:10.1111/comt.12048

Geise, S., & Kamps, K. (2012, May). *"Physical attractiveness": On the theoretical and methodological conceptualization of a critical predictor variable in political communication studies*. Paper presented at International Communication Association Annual Conference, Phoenix, AZ.

Gibson, R., & Zillmann, D. (2000). Reading between the photographs: The influence of incidental pictorial information on issue perception. *Journalism & Mass Communication Quarterly*, *77*, 355-366. doi:10.1177/107769900007700209

Grittmann, E. (2012). Visuelle Konstruktionen von Klima und Klimawandel in den Medien. Ein Forschungsüberblick [Visual constructions of climate and climate change in the media. A research overview]. In I. Neverla & M. S. Schäfer (Eds.), *Das Medien-Klima* [The media climate] (pp. 171-196). Wiesbaden, Germany: VS Verlag für Sozialwissenschaften.

Grittmann, E. (2013). Visual frames—Framing visuals. Zum Zusammenhang von Diskurs, Frame und Bild in den Medien am Beispiel des Klimawandeldiskurses [Visual Frames—Framing Visuals. On the relationship of discourse, frame and image in the media using the example of climate change discourse]. In S. Geise & K. Lobinger (Eds.), *Visual framing: Perspektiven und Herausforderungen der Visuellen Kommunikationsforschung* [Visual framing: Perspectives and challenges of visual communication research] (pp. 95-119). Köln, Germany: Herbert von Halem.

Grittmann, E. (2014). Between risk, beauty and the sublime: The visualization of climate change in the German Press during COP09. In T. Nocke & B. Schneider (Eds.), *Image. Image politics of climate change. Visualizations, imaginations, documentations* (pp. 127-151). Bielefeld, Germany: Transcript.

Haagerup, U. (2015). *Constructive news: Warum "bad news" die Medien zerstören und wie Journalisten mit einem völlig neuen Ansatz wieder Menschen berühren* [Constructive news: Why negativity destroys the media and democracy—And how to improve journalism of tomorrow] (1st German ed.). Salzburg, Austria: Oberauer.

Hadler, M., & Haller, M. (2011). Global activism and nationally driven recycling: The influence of world society and national contexts on public and private environmental behavior. *International Sociology*, *26*, 315-345. doi:10.1177/0268580910392258

Hansen, A., & Machin, D. (2008). Visually branding the environment: Climate change as a marketing opportunity. *Discourse Studies*, *10*, 777-794. doi:10.1177/1461445608098200

Hobson, K., & Niemeyer, S. (2013). "What sceptics believe": The effects of information and deliberation on climate change scepticism. *Public Understanding of Science*, *22*, 396-412. doi:10.1177/0963662511430459

Hoijer, B. (2010). Emotional anchoring and objectification in the media reporting on climate change. *Public Understanding of Science*, *19*, 717-731. doi:10.1177/0963662509348863

Kaiser, J., & Rhomberg, M. (2015). Questioning the doubt: Climate skepticism in German newspaper reporting on COP17. *Environmental Communication*, 1-19. Advance online publication. doi:10.1080/17524032.2015.1050435

Leiserowitz, A. (2006). Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Climatic Change*, *77*(1-2), 45-72. doi:10.1007/s10584-006-9059-9

Lester, L., & Cottle, S. (2009). Visualizing climate change: Television news and ecological citizenship. *International Journal of Communication*, *3*, 920-936.

Liebes, T., & Katz, E. (1993). *The export of meaning: Cross-cultural readings of Dallas* (2nd ed.). Cambridge, MA: Polity Press.

Lobinger, K., & Brantner, C. (2015). Likable, funny or ridiculous? A Q-sort study on audience perceptions of visual portrayals of politicians. *Visual Communication*, *14*, 15-40.

Mahony, M., & Hulme, M. (2014). The color of risk: Expert judgment and diagrammatic reasoning in the IPCC's "Burning Embers." In B. Schneider & T. Nocke (Eds.), *Image: v. 55. Image politics of climate change. Visualizations, imaginations, documentations* (pp. 105-124). Bielefeld, Germany: Transcript.

Manzo, K. (2010a). Beyond polar bears? Re-envisioning climate change. *Meteorological Applications*, *17*, 196-208. doi:10.1002/met.193

Manzo, K. (2010b). Imaging vulnerability: The iconography of climate change. *Area*, *42*, 96-107. doi:10.1111/j.1475-4762.2009.00887.x

McKeown, B., & Thomas, D. (2013). *Q methodology. Quantitative applications in the social sciences* (Vol. 66, 2nd ed.). Los Angeles, CA: Sage.

Metag, J., Füchslin, T., & Schäfer, M. S. (2015). Global warming's five Germanys: A typology of Germans' views on climate change and patterns of media use and information. *Public Understanding of Science*. Advance online publication. doi:10.1177/0963662515592558

Michelle, C., Davis, C. H., & Vladica, F. (2012). Understanding variation in audience engagement and response: An application of the composite model to receptions of avatar (2009). *The Communication Review*, *15*, 106-143. doi:10.1080/10714421.2012.674467

Müller, F. H., & Kals, E. (2004). Die Q-Methode. Ein innovatives Verfahren zur Erhebung subjektiver Einstellungen und Meinungen [Q-method. An innovative approach to measure subjective attitudes and opinions]. *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*, *5*(2), 17. Retrieved from http://nbn-resolving.de/urn:nbn:de:0114-fqs0402347

Nicholson-Cole, S. A. (2005). Representing climate change futures: A critique on the use of images for visual communication. *Computers, Environment and Urban Systems*, *29*, 255-273. doi:10.1016/j.compenvurbsys.2004.05.002

Niemeyer, S. (2013). *Advance Q* [Computer software].

O'Neill, S. J. (2013). Image matters: Climate change imagery in US, UK and Australian newspapers. *Geoforum*, *49*, 10-19. doi:10.1016/j.geoforum.2013.04.030

O'Neill, S. J., Boykoff, M., Niemeyer, S., & Day, S. A. (2013). On the use of imagery for climate change engagement. *Global Environmental Change*, *23*, 413-421. doi:10.1016/j.gloenvcha.2012.11.006

O'Neill, S. J., & Hulme, M. (2009). An iconic approach for representing climate change. *Global Environmental Change*, *19*, 402-410. doi:10.1016/j.gloenvcha.2009.07.004

O'Neill, S. J., & Nicholson-Cole, S. (2009). "Fear won't do it": Promoting positive engagement with climate change through visual and iconic representations. *Science Communication*, *30*, 355-379. doi:10.1177/1075547008329201

O'Neill, S. J., & Smith, N. (2014). Climate change and visual imagery. *Wiley Interdisciplinary Reviews: Climate Change*, *5*, 73-87. doi:10.1002/wcc.249

Orchard, L. J., Fullwood, C., Morris, N., & Galbraith, N. (2014). Investigating the Facebook experience through Q Methodology: Collective investment and a "Borg" mentality. *New Media & Society*, *17*, 1547-1565. doi:10.1177/1461444814530099

Peters, H. P., & Heinrichs, H. (2008). Legitimizing climate policy: The "risk construct" of global climate change in the German mass media. *International Journal of Sustainability Communication*, *3*, 14-36.

Pleger, S. (2013). *Die visuelle Medienkommunikation zum Klimawandel. Eine Untersuchung am Beispiel der internationalen Bildberichterstattung* [The visual media communication on climate change. A study using the example of the international photojournalism](Master's Thesis). University of Hamburg.

Powell, T. E., Boomgaarden, H. G., de Swert, K., & de Vreese, C. H. (2015). A clearer picture: The contribution of visuals and text to framing effects. *Journal of Communication*, *65*, 997-1017. doi:10.1111/jcom.12184

Rebich-Hespanha, S., Rice, R. E., Montello, D. R., Retzloff, S., Tien, S., & Hespanha, J. P. (2015). Image themes and frames in US print news stories about climate change. *Environmental Communication*, *9*, 491-519. doi:10.1080/17524032.2014.983534

Rüegg, I. (2015). *Klimawandel visuell. Eine Bildanalyse der Klimaberichterstattung in deutschsprachigen Zeitungen* (Master's thesis). Universität Zürich, Zürich, Switzerland.

Schäfer, M. S. (forthcoming). Climate change communication in Germany. In M. Nisbet, S. Ho, E. Markowitz, S. O'Neill, M. S. Schäfer & J. Thaker (Eds.), *Oxford encyclopedia of climate change communication*. New York, NY: Oxford University Press.

Schäfer, M. S., Ivanova, A., & Schmidt, A. (2014). What drives media attention for climate change? Explaining issue attention in Australian, German and Indian print media from 1996 to 2010. *International Communication Gazette*, *76*, 152-176. doi:10.1177/1748048513504169

Schäfer, M. S., & Schlichting, I. (2014). Media representations of climate change: A meta-analysis of the research field. *Environmental Communication*, *8*, 142-160. doi:10.1080/17524032.2014.914050

Schmidt, A., Ivanova, A., & Schäfer, M. S. (2013). Media attention for climate change m. *Global Environmental Change*, *23*, 1233-1248. doi:10.1016/j.gloenvcha.2013.07.020

Schneider, B. (2009). Wechselseitige Durchdringung von Wissenschaft und Medien am Bsp. der Hockeystick-Grafik [Mutual penetration of science and media at Ex. The hockey stick graphics]. In K. Harrasser, H. Lethen & E. Timm (Eds.), *Sehnsucht nach Evidenz. Zeitschrift für Kulturwissenschaften* [Longing for evidence. Journal of Cultural Studies] (1st ed., pp. 41-55). Bielefeld, Germany: Transcript.

Schneider, B. (2012). Climate model simulation visualization from a visual studies perspective. *Wiley Interdisciplinary Reviews: Climate Change*, *3*, 185-193. doi:10.1002/wcc.162

Schneider, B., & Nocke, T. (Eds.). (2014). *Image: v. 55. Image politics of climate change: Visualizations, imaginations, documentations*. Bielefeld, Germany: Transcript.

Singer, J. B. (1997). Changes and consistencies: Newspaper journalists contemplate an online future. *Newspaper Research Journal*, *18*, 2-18.

Slocum, R. (2004). Polar bears and energy-efficient lightbulbs: Strategies to bring climate change home. *Environment and Planning D: Society and Space*, *22*, 413-438. doi:10.1068/d378

Smith, N. W., & Joffe, H. (2009). Climate change in the British press: The role of the visual. *Journal of Risk Research*, *12*, 647-663. doi:10.1080/13669870802586512

Stephenson, W. (1953). *The study of behavior: Q-technique and its methodology*. Chicago, IL: University of Chicago Press.

Walsh, L. (2010). Before climategate: Visual strategies to integrate ethos across the "is/ought" divide in the IPCC's climate change 2007: Summary for policy makers. *Poroi*, *6*(2), 33-61.

Weingart, P., Engels, A., & Pansegrau, P. (2000). Risks of communication: Discourses on climate change in science, politics, and the mass media. *Public Understanding of Science*, *9*, 261-283. doi:10.1088/0963-6625/9/3/304

Wessler, H., Lück, J., & Wozniak, A. (2014). *Sustainable media events? Production and discursive effects of staged global political media events in the area of climate change* (Research project). Retrieved from http://climate.uni-mannheim.de/Home/

Whitmarsh, L., O'Neill, S., & Lorenzoni, I. (2011). *Engaging the public with climate change: Behaviour change and communication*. Washington, DC: Earthscan.

Wozniak, A., Lück, J., & Wessler, H. (2015). Frames, stories, and images: The advantages of a multimodal approach in comparative media content research on climate change. *Environmental Communication*, *9*, 469-490. doi:10.1080/17524032.2014.981559

Author Biographies

Julia Metag is a senior teaching and research associate (postdoctoral) in communication sciences at the University of Zurich. Her research focuses on science communication, political communication, and media effects.

Mike S. Schäfer is a professor of science communication at the University of Zurich and director of the university's Center for Higher Education and Science Studies. His research focuses on science communication, climate change communication, and political communication.

Tobias Füchslin is a student associate at the Institute of Mass Communication and Media Research, University of Zurich.

Tjado Barsuhn is a bachelor's student in media and communication studies at the University of Hamburg.

Katharina Kleinen-von Königslöw is a professor of political communication at the University of Zurich. Her research focuses on the transnationalization, fragmentation, and entertainization of political communication.

8 Author Contributions

8.1 List of Authors

Tobias Füchslin: TF
Mike S. Schäfer: MS
Julia Metag: JM
Eszter Hargittai: EH
Katharina Kleinen von Königslöw: KK
Tjado Barshun: TB
Adrian Rauchfleisch: AR
Silje Kristiansen: SK
Marko Kovic: MK
Michaela Meier: MM
Laurits Bromme: LB

8.2 Publications and Author Contributions

Article	Planning	Theory	Data Collection	Methods /Analysis	Writing
Füchslin, T. (2019): Science communication scholars use more and more segmentation analyses. Can we take them to the next level? *Public Understanding of Science*. https://doi.org/10.1177/0963662519850086	**TF**	**TF**	**TF**	**TF**	**TF**
Füchslin, T./ Schäfer, M. S./ Metag J. (2019): Who wants to be a citizen scientist? Identifying the overall potential of citizen science and target segments in Switzerland. *Public Understanding of Science.* https://doi.org/10.1177/0963662519852020	**TF** MS JM	**TF** MS JM	MS & JM	**TF** MS JM	**TF** MS JM
Füchslin, T./ Schäfer, M. S. / Metag, J. (2018): A Short Survey Instrument to Segment Populations According to Their Attitudes Toward Science. Scale Development, Optimization and Assessment. *Environmental Communication*, 12 (8), 1095-1108. https://doi.org/10.1080/17524032.2018.1461673	**TF** MS JM	**TF** MS JM	MS & JM	**TF** MS JM	**TF** MS JM
Metag, J./ Maier, M./ Füchslin, T./ Bromme, L./ Schäfer, M. S. (2018): Between Active Seekers and Non-Users: Segments of Science-related Media Usage in Switzerland and Germany. *Environmental Communication*, 12 (8), 1077-1094. https://doi.org/10.1080/17524032.2018.1463924	JM & MM **TF** & LB MS	JM & MM MS **TF** & LB	JM & MM MS	**TF** & LB JM & MM MS	JM & MM **TF** & LB MS

Kovic, M./ Füchslin, T. (2018): Probability and conspiratorial thinking. *Applied Cognitive Psychology*, 32(3), 390-400. https://doi.org/10.1002/acp.3408	MK **TF**	MK **TF**	MK **TF**	MK **TF**	MK **TF**
Article	Planning	Theory	Data Collection	Methods /Analysis	Writing
Hargittai, E./ Füchslin, T./ Schäfer, M. S. (2018): How Do Young Adults Engage With Science and Research on Social Media? Some Preliminary Findings and an Agenda for Future Research. *Social Media + Society*, 4 (3). https://doi.org/10.1177/2056305118797720	EH MS **TF**	**TF** MS EH	EH	EH MS **TF**	EH **TF** MS
Schäfer, M. S./Füchslin, T./ Metag, J./ Kristiansen, S./ Rauchfleisch, A. (2018): The Different Audiences of Science Communication. A Segmentation Analysis of the Swiss Population's Perceptions of Science and their Information and Media Use Patterns. *Public Understanding of Science*, 27 (7), 836-856. https://doi.org/10.1177/0963662517752886	MS **TF** JM	MS **TF** JM	MS & JM AR & SK	**TF** MS JM AR & SK	MS **TF** JM AR & SK
Metag, J./ Schäfer, M. S:/ Füchslin, T/ Barsuhn, T./ Kleinen-von Königslöw, K. (2016): Perceptions of Climate Change Imagery: Evoked Salience and Self-Efficacy in Germany, Switzerland and Austria. *Science Communication*, 38 (2), 197-227. https://doi.org/10.1177/1075547016635181	JM MS KK **TF** & TB	JM MS KK **TF** & TB	**TF** TB KK JM MS	JM MS **TF** & TB KK	JM MS KK **TF** & TB
Metag, J./ Füchslin, T./ Schäfer, M. S. (2015): Global Warming's Five Germanys. A Typology of Germans' Views on Climate Change and their Patterns of Media Use and Information. *Public Understanding of Science*, 26(4), 434-451. https://doi.org/10.1177/0963662515592558	JM MS **TF**	JM MS **TF**	MS	**TF** JM MS	JM **TF** MS

Legend: Extent of author contribution ordered ascending by row. Lead author(s) in first row.

9 CV Tobias Füchslin

Tobias Füchslin, MA

Geeringstrasse 87
CH-8049 Zürich
+41 79 705 89 60
t.fuechslin@ikmz.uzh.ch

December 23rd, 1989
Swiss

Education

July 2016 – August 2019	Doctoral program in communication science, focus: science communication
September 2013 – June 2015	MA in media and communication sciences, minor: popular cultures, University of Zürich final mark 5,7
September 2010 – June 2013	BA in media and communication sciences, minor: popular cultures, University of Zürich final mark 5,3
September 2009 – June 2010	Some credits in mathematics and physics, ETH Zürich
July 2002 – June 2008	Gymnasium (academic high school), «Institut Dr. Pfister», Oberägeri, Zug

Career

September 2019 – present	Researcher and Coordinator, Expert Group «Communicating Sciences and Arts in Times of Digital Media», Swiss Academies of Arts and Sciences
July 2016 – August 2019	Research and Teaching Associate, University of Zürich, Department of Communication and Media Research (IKMZ), Division Science, Crisis & Risk Communication
August 2015 – February 2016	Marketing-assistant at myclimate (alternative service)
September 2013 – June 2015	Student Associate , University of Zürich, Department of Communication and Media Research (IKMZ), Division Science, Crisis & Risk Communication
	Tutorage at BA-research seminar on media and minorities
	Seminar teacher for empirical methods in the social sciences
September 2010 – June 2013	Four-time seminar teacher for empirical methods in the social sciences

Awards

- «Candoc» full dissertation scholarship from the University of Zurich.
- Young Scholar Award (2nd place) by the German Communication Association (DGPuK), Düsseldorf, Germany, 30.3-1.4.2017, concerning the article: Füchslin, T./ Schäfer, M. S./ Metag, J./ Kristiansen, S./ Rauchfleisch, A.: The Different Audiences of Science Communication. A Segmentation Analysis of the Swiss Population's Perceptions of Science and their Information and Media Use Patterns.

Academic Publications with Peer-Review

- Füchslin, T. (2019): Science communication scholars use more and more segmentation analyses. Can we take them to the next level? *Public Understanding of Science*, 28 (7), 854-864. *https://doi.org/10.1177/0963662519850086*
- Füchslin, T./ Schäfer, M. S./ Metag J. (2019): Who wants to be a citizen scientist? Identifying the overall potential of citizen science and target segments in Switzerland. *Public Understanding of Science*, 28 (6), 652-668. *https://doi.org/10.1177/0963662519852020*
- Füchslin, T./ Schäfer, M. S. / Metag, J. (2018): A Short Survey Instrument to Segment Populations According to Their Attitudes Toward Science. Scale Development, Optimization and Assessment. *Environmental Communication*, 12 (8), 1095-1108. *https://doi.org/10.1080/17524032.2018.1461673*
- Metag, J./ Maier, M./ Füchslin, T./ Bromme, L./ Schäfer, M. S. (2018): Between Active Seekers and Non-Users: Segments of Science-related Media Usage in Switzerland and Germany. *Environmental Communication*, 12 (8), 1077-1094. *https://doi.org/10.1080/17524032.2018.1463924*
- Kovic, M./ Füchslin, T. (2018): Probability and conspiratorial thinking. *Applied Cognitive Psychology*. *https://doi.org/10.1002/acp.3408*
- Hargittai, E./ Füchslin, T./ Schäfer, M. S. (2018): How Do Young Adults Engage With Science and Research on Social Media? Some Preliminary Findings and an Agenda for Future Research. *Social Media + Society*. *https://doi.org/10.1177/2056305118797720*
- Schäfer, M. S./Füchslin, T./ Metag, J./ Kristiansen, S./ Rauchfleisch, A. (2018): The Different Audiences of Science Communication. A Segmentation Analysis of the Swiss Population's Perceptions of Science and their Information and Media Use Patterns. *Public Understanding of Science*. *https://doi.org/10.1177/0963662517752886*
- Füchslin, T. (2016): What are you folding for? Nutzungsmotivationen von Citizen Science Online Games und ihre Lerneffekte [Motivations to use Citizen Science Online Games and their learning effects]. *merzWissenschaft*, 60 (6),110-122.
- Metag, J./ Schäfer, M. S:/ Füchslin, T/ Barsuhn, T./ Kleinen-von Königslöw, K. (2016): Perceptions of Climate Change Imagery: Evoked Salience and Self-Efficacy in Germany, Switzerland and Austria. *Science Communication*, 38 (2), 197-227. *https://doi.org/10.1177/1075547016635181*
- Metag, J./ Füchslin, T./ Schäfer, M. S. (2015): Global Warming's Five Germanys. A Typology of Germans' Views on Climate Change and their Patterns of Media Use and Information. *Public Understanding of Science.* *https://doi.org/10.1177/0963662515592558*

Academic Presentations and Posters

- Füchslin, T./ Schäfer, M. S./ Metag, J. (2019): Who Wants To Be a Citizen Scientist? Identifying the Overall Potential of Citizen Science and Target Segments in Switzerland. Paper presented at the 69th Annual Conference of the International Communication Association (ICA) in Washington DC (USA), 24.-28. May.

- Füchslin, T./ Schäfer, M. S./ Metag, J. (2019): Who Wants To Be a Citizen Scientist? Identifying the Overall Democratic Potential of Citizen Science and Target Segments in Switzerland and Germany. Presentation at the 72nd Annual World Association for Public Opinion Research (WAPOR) Conference in Toronto (Canada), 19.-21. May.

- Füchslin, T. (2019) Who Wants To Be a Citizen Scientist? Identifying General Characteristics and Specific Audiences of Potential Citizen Scientists in Switzerland. Presentation at the Annual Conference of the Section Science Communication of the German Communication Association (DGPuK) in Braunschweig (Germany), 6.-8. February.

- Füchslin, T./ Rauchfleisch, A./ Keller, T./ Schäfer, M. S. (2018): The March for Science on Twitter: When Science Meets Partisan Politics. Zweite Jahrestagung der Fachgruppe Wissenschaftskommunikation der Deutschen Gesellschaft für Publizistik und Kommunikationswissenschaft (DGPuK). Friedrichshafen, Deutschland, 01.02. bis 03.02.2018.

- Füchslin, T./ Schäfer, M. S./ Metag, J./ Kristiansen, S./ Rauchfleisch, A. (2017): Audiences of Science Communication in Switzerland - An Audience Segmentation Analysis. Paper accepted at the 67th annual conference of the International Communication Association (ICA). San Diego, USA, 25. - 29.5.2017.

- Füchslin, T. (2017): What are you folding for? Use motivations behind Citizen Science Online Games and their learning effects. Paper accepted at the 67th annual conference of the International Communication Association (ICA). San Diego, USA, 25. - 29.5.2017.

- Hargittai, E./ Füchslin, T./ Schäfer, M. S. (2017): How Young Adults Engage with Science on Social Media. Extended abstract (poster) at the 67th annual conference of the International Communication Association (ICA). San Diego, USA, 25. - 29.5.2017.

- Füchslin, T. (2017): Scientific Online Literacy – Konzeption und Anwendung. Abstract accepted at the Doktorandenfenster der Jahrestagung der Fachgruppe Wissenschaftskommunikation der Deutschen Gesellschaft für Publizistik und Kommunikationswissenschaft (DGPuK). Landau, Deutschland, 27.04. - 29.04.2017.

- Füchslin, T./ Schäfer, M. S./ Metag, J./ Kristiansen, S./ Rauchfleisch, A. (2017): Die vier Publika der Wissenschaftskommunikation. Eine Analyse der Segmentierung der Schweizer Bevölkerung. Paper accepted at the 62th annual meeting of the Deutschen Gesellschaft für Publizistik und Kommunikationswissenschaft (DGPuK). Düsseldorf, Deutschland, 30.3 - 1.4.2017.

- Füchslin, T. (2016): Scientific Online Literacy – Konzeption und Anwendung. Abstract accepted at the Doktorandenfenster der Jahrestagung der Fachgruppe Digitale Kommunikation der der Deutschen Gesellschaft für Publizistik und Kommunikationswissenschaft (DGPuK), Braunschweig, Deutschland, 3.11 - 5.11.2016.

- Metag, J./ Füchslin, T./ Schäfer, M. S. (2015): Global Warming's Five Germanys – Eine Typologie deutscher Rezipienten hinsichtlich ihrer Einstellungen, Verhaltensweisen und Kommunikationsaktivitäten zum Thema Klimawandel. Extended Abstract accepted at the Jahrestagung «Wissenschaftskommunikation zwischen Risiko und (Un)Sicherheit» der Ad-Hoc-Gruppe «Wissenschaftskommunikation» der DGPuK, Jena, 30.01.-31.01.2015.

In the Media

- The Skeptic's Guide to the Universe, Episode #668, Feature Interview, April 28 2018 *https://www.theskepticsguide.org/podcast/sgu/668*

- Radio SRF2: Kultur Kompakt: Von Wissenschaftsenthusiasten und Wissenschaftsmuffeln, February 7 2018. Link

- Radio SRF3: Klickmagneten: Die Wissenschaftschannels auf YouTube, July 28.2016. Link

Other Activities

- Project Member: Science Barometer Switzerland
- Reviewer for *Public Understanding of Science*, *Environmental Communication*, *Journal of Communication Management*
- Founding member, former board member and podcast host: Skeptiker Schweiz – Verein für kritisches Denken

Universität Zürich[UZH]

Philosophische Fakultät
Studiendekanat

Universität Zürich
Philosophische Fakultät
Studiendekanat
Rämistrasse 69
CH-8001 Zürich
www.phil.uzh.ch

Erklärung

Hiermit erkläre ich, dass die Dissertation von mir selbst ohne unerlaubte Beihilfe verfasst worden ist und diese Dissertation noch an keiner anderen Fakultät eingereicht wurde.

Ort und Datum Unterschrift

Zürich, 23.9.2019